DOCUMENT RESUME

ED 236 039	SE 043 321
AUTHOR	Kolb, James A.
TITLE	Marine Biology and Oceanography, Grades Seven and Eight.
INSTITUTION	Educational Services District 114, Marine Science Center, Poulsbo, WA.
SPONS AGENCY	Washington Office of the State Superintendent of Public Instruction, Olympia.
PUB DATE	[81]
NOTE	761p.; For related documents, see SE 043 319-323.
AVAILABLE FROM	James A. Kolb/Marine Science Center, 17771 Fjord Drive, NE, Poulsbo, WA 98370 ($25.00).
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF04 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Ecology; Environmental Education; *Geology; Grade 7; Grade 8; Junior High Schools; Map Skills; *Marine Biology; *Marine Education; Migration; Mining; Natural Resources; Navigation; *Oceanography; Physical Geography; *Science Activities; Science Education; *Secondary School Science; Topography; Water Resources
IDENTIFIERS	*Plate Tectonics; Whales

ABSTRACT

This unit, one of a series designed to develop and foster an understanding of the marine environment, presents marine science activities for students in grades 7 and 8. The unit, focusing on life in the sea and the physical factors which influence that life, is divided into sections dealing with: (1) the theory of plate tectonics; (2) ocean floor topography; (3) the hydrologic cycle and weather; (4) adaptation and diversity; (5) marine food chains; (6) currents; (7) mining the ocean floor; (8) whaling; (9) offshore oil production; (10) boating and (11) the California gray whale population. Each section has a student text with related activities. Each student text is preceded by a teacher background section containing hints on how to use the section, additional information, and items requiring advanced planning. Each activity is preceded by a teacher background section providing additional information about the activity, including teaching hints and answer key for activities. Important vocabulary words/terms are listed in the teacher background sections; they are underlined in the student text. Activities are designed to enhance reading as well as investigational skills; several activities provide practice in mathematics skills. Although all activities can be modified to suit individual needs or be used "as is," it is strongly recommended that they be performed along with the readings/discussions found in student text material. (JM)

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7-8 MARINE BIOLOGY AND OCEANOGRAPHY

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MARINE BIOLOGY AND OCEANOGRAPHY

GRADES SEVEN AND EIGHT

MARINE SCIENCE PROJECT: FOR SEA
Educational Service District 114
P.O. Box 155, Federal Building
Port Townsend, Washington 98368

ESEA TITLE IV-C

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MARINE BIOLOGY AND OCEANOGRAPHY

GRADES SEVEN AND EIGHT

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MARINE BIOLOGY AND OCEANOGRAPHY

GRADES SEVEN AND EIGHT

INTRODUCTION

The history of the United States is strongly tied to the seas. The future of the United States will also be strongly tied to the marine world. It is important that the leaders and the citizenry alike have a familiarity with the marine environment that will permit them to make wise choices in resolving the conflicts that are sure to arise over use of the ocean's resources. Marine Biology and Oceanography is designed to contribute to the knowledge necessary to make these sound decisions. In the development of Marine Biology and Oceanography, our goal has been to provide an opportunity for both the teacher and the student to become aware of the living and non-living factors that shape the life of the sea.

Marine Biology and Oeanography deals with life in the sea and with the physical factors which influence that life. While each activity has been sesigned to stand alone, presented together they provide a coherent introduction to the marine sciences. The life history of the California gray whale helps provide continuity.

It is recommended that the teacher incorporate his or her own ideas, experiences, and background to elaborate the subject material. It is important to develop the natural enthusiasm students have for learning about the sea. This is the time to add a bulletin board dealing with the marine world to your classroom. Displays of living and non-living marine creatures are also recommended. Use your imagination to create an exciting classroom atmosphere. National Geographic magazines are excellent sources of pictures. Incorporate some of the books listed in the "Bibliography of Selected Books about the

Marine Environment" section into your reading program. Investigate the audio-visual materials available from your supplier. Have students bring in their shell collections and other related items. These units have the potential for not only being worthwhile, they can be fun!

The guide is divided into several sections. Each section has a student text and student activities. Each student text is preceded by a "Teacher Background" section which contains: hints on how to use the section, additional information, and items for which advanced planning is required. Important vocabulary terms are listed in the "Key Word" section of each "Teacher Background." They are also underlined in the text. The words are defined in the text, either directly or by context. All of the sections have activities accompanying the text. Most activities require few materials not ordinarily found in secondary science classrooms. It is strongly recommended that the activities be performed along with the reading and discussion of the text. Each activity is also preceded by a "Teacher Background" section. This section gives additional information about the activity including teaching hints and answer key. The activities are designed to enhance reading skills as well as investigational skills. Some activities provide practice in math skills. The activities can be modified to suit your particular needs, but will work "as is."

Skim the contents of the guide to discover the organizational scheme. Please read the text and activities before you use them. The materials have all been prepared with ease of duplication in mind. Please feel free to duplicate any and all materials you need to effectively utilize this unit with your class.

Many of the laboratory experiences originated or have been utilized at the Marine Science Center. Teachers using these materials are given the opportunity to use the many resources available through the Marine Science Center staff. Our staff is available to you to give assistance in providing resource material and in setting up the unit of study. Please feel free to contact one of our staff members by calling (206) 779-5549.

At the end of the text and activity section, you will find a "Send-in Page." We would like you to use it to let us know how much you liked or disliked the units. If you have some marine activity that you have tried successfully with your students, please let us know about it. Perhaps we can incorporate it in future revisions.

This unit is one of a series designed to develop and foster an understanding of the marine environment. Other units in the series include:

Marine Science Activities, Grade 2

Marine Science Career Awareness, Grade 4

Marine Science Activities - The Marine Environment, Grade 6

Marine Biology and Oceanography, Grades 9 - 12

Marine Biology and Oceanography, Grades 7 - 8, has been prepared with funds from ESEA Title IV-C Grant Number 35462 administered by Educational Service District 114 and the Superintendent of Public Instruction.

James A. Kolb
Project Developer
Author/Editor

A CONCEPTUAL SCHEME FOR MARINE AND COASTAL ENVIRONMENT STUDIES

BY MAURA BEENS TYRRELL AND ROBERT W. STEGNER

1. AN ABUNDANCE OF WATER MAKES THE EARTH UNIQUE IN OUR SOLAR SYSTEM.

- 1.1 Water has a unique combination of chemical and physical properties.
  - 1.11 The chemical and physical behavior of water results in part from the geometry of the water molecule.
  - 1.12 Within the range of temperatures encountered on earth, water exists in three states: solid, liquid, and gas.
  - 1.13 Water exchanges large amounts of heat as it changes in state.
- 1.2 Water in the environment contains a variety of substances in suspension and in solution.
  - 1.21 Water is a very effective solvent.
  - 1.22 Dissolved and suspended substances affect the properties of water.
  - 1.23 Water in nature usually contains gases, organic compounds and mineral salts.
  - 1.24 Many elements dissolved in water are recycled through biological, geological, and chemical systems.

2. AQUATIC ENVIRONMENTS INTERACT WITH THE EARTH AND ITS ATMOSPHERE.

- 2.1 Most of the earth's water is in the oceans.
  - 2.11 Oceans formed early in the history of the earth.
  - 2.12 The earth's surface water is constantly recycled through the oceans.
- 2.2 The ocean waters are influenced by the earth's rotation, revolution, and position in the solar system.
  - 2.21 Ocean current patterns are affected by the absorption of solar energy.
  - 2.22 Ocean current patterns are affected by the earth's rotation.
  - 2.23 Tides result from gravitational forces of the earth, the moon, and the sun.
- 2.3 Energy is transferred wherever bodies of water meet the land or atmosphere.
  - 2.31 Atmospheric movements generate waves, surface currents, and coastal winds.
  - 2.32 Moving water shapes land forms.
  - 2.33 Subsurface topography is constantly changing.
  - 2.34 Land and sea floor movements generate waves.
  - 2.35 The aquatic environment helps to stabilize the earth's climate.

2.4 Materials carried from land masses influence the physical and chemical features of rivers, lakes and coastal zones.
  2.41 Water, ice and wind carry minerals, nutrients, sediments and fresh water into rivers, lakes and coastal zones.
  2.42 Fresh water from the land dilutes the coastal water.

3. AQUATIC ORGANISMS INTERACT IN COMPLEX ECOSYSTEMS.

3.1 Life probably originated in the marine environment.
  3.11 Water facilitated the chemical evolution of organic compounds and coacervates.
  3.12 Chemical evolution resulted in heterotrophic systems.
  3.13 Autotrophs evolved from heterotrophs.
  3.14 Aquatic environments have supported the evolution of a diversity of species.
3.2 Aquatic organisms are adapted to their environments in different ways.
  3.21 Aquatic organisms are adapted developmentally, structurally, functionally, and behaviorally to their environments.
  3.22 Organisms in aquatic communities interact in balance with their environment and with one another.
  3.23 Populations of aquatic organisms are unevenly distributed.
3.3 Aquatic ecosystems depend on a constant flow of energy and the recycling of materials.
  3.31 Energy for the maintenance of aquatic ecosystems comes from the sun.
  3.32 Aquatic plants convert solar energy to food energy.
  3.33 Aquatic organisms transfer energy and materials through food webs.
  3.34 Aquatic bacteria reduce organic materials to simpler forms.

3.4 The stability of aquatic ecosystems tends to be directly proportional to the diversity of their populations and the complexity of relationships among them.

4. PEOPLE ARE PART OF AQUATIC ECOSYSTEMS.

4.11 Aquatic environments have affected the course of history and the development of human cultures.

  4.11 Oceans, lakes, and rivers have served as routes for the dispersal of human populations and cultures and for commercial transport.
  4.12 Proximity to aquatic environments and the availability of aquatic resources have influenced the cultures of many societies.
4.2 People's activities may alter the aquatic ecosystem.
  4.21 People collect and culture aquatic resources.
  4.22 Exploitation of aquatic environments can cause depletion of many marine and freshwater species and the degradation of habitats.
  4.23 People are changing aquatic ecosystems by adding pollutants to land, to air and to water.
4.3 Existing technology is capable of maintaining the health and usefulness of aquatic ecosystems.
  4.31 The maintenance of the health and usefulness of aquatic environments depends on value judgments and ethical considerations.
  4.32 Regional and international agreements will be essential for the conservation of aquatic resources.

MARINE AQUARIA IN THE CLASSROOM

From kindergarten to graduate school, the marine aquarium arouses interest and enthusiasm. Traditionally, marine aquaria have been very expensive and difficult to operate. Recent technological improvements have reduced the cost and labor involved in maintaining a marine aquarium. Teachers should give every consideration to the establishment of a marine aquarium in the classroom.

Before embarking on a marine aquarium project, some basic questions need to be resolved. These include: How much can I afford (do I want) to spend in time? in effort? A very simple set-up to keep hermit crabs can be had for a few dollars, while an elaborate temperature-controlled aquarium can cost several thousand dollars.

Regardless of the type of aquarium chosen, some facts pertain to all:

1. Aquarium tank -	use only tanks made from all glass, plastic, epoxy-coated wood, or fiberglass. No metal edges. While a 10 gallon aquarium may be used in some cases, 20 gallon size is the preferred minimum.
2. Sub-gravel filter -	a good sub-gravel filter should be employed to help control biological wastes.
3. Air pump -	you can seldom have too much air. Get a pump with a capacity high enough to effectively run the sub-gravel filtration system.
4. Gravel filtrant -	use dolomite, crushed coral rock, or crushed oyster shell. Builders' gravel has iron and similar materials which will harm or kill marine organisms.
5. Thermometer/Hydrometer -	tools useful in determining the salinity and temperature of the water.
6. Seawater -	synthetic sea salts may be used to make salt water solutions if you are more than a day's drive from natural seawater.
7. Food -	depends upon the type of organism. Use only high quality foods and remove uneaten food from aquarium.

If you buy a marine aquarium kit, instructions for set-up will be included. Otherwise, a few hints are given below:

1. Talk to people who have had marine aquaria. (e.g., other teachers, pet shops, etc.) Their assistance can be invaluable.

2. Place the aquarium in desired location, away from direct sunlight, but near an electrical outlet.

3. Install sub-gravel filter.

4. Wash gravel in tap water. Spread evenly over the filter.

5. Fill tank with correct amount of water needed to make sea salt solution (follow directions of manufacturer), or fill to 1 or 2 inches from top with natural sea water if available.

6. Run filtration system for 24 hours to mix solution.

7. Shut off filter. Check specific gravity by floating hydrometer and reading it at the water-line: it should read between 1.021 and 1.023 when the water temperature is 68-77°F (20-25°C). If necessary, adjust by adding tap water to lower reading.

8. Run filter for 14 days. Some aquarists recommend placing one or two hardy specimens in the tank for this period. If available, hermit crabs or the like should be added to help condition the water.

9. Add specimens to tank. If you order the animals from a biological supply house, they will come with directions. Otherwise, open each plastic bag of specimens in subdued light and float it on top of the water in the aquarium for 15 to 30 minutes. In this period trickle water from the tank into the bags to slowly equalize temperature and salinity. This is the crucial step. Now add animals to tank, one at a time. (If animals act nervous or contract, stop operation until they have adjusted.)

10. The specimens will live several months without being fed, but to keep them healthy, adopt a simple, regular feeding program. Feed carnivorous invertebrates (sea anemones, crabs, horseshoe crabs, starfish, etc.) once a week: they take small minnows, shrimp, earthworms, bits of lean beef. Filter-feeders (barnacles, hydroids, sea cucumbers, clams, etc.) eat Daphnia, brine shrimp, algae, protozoa, or dried fish foods. Herbivorous species (sea hares, sea urchins, turban snails, etc.) may be fed lettuce or spinach. Avoid water pollution --- remove all uneaten food.

Not all plants and animals are suitable for marine aquaria. Sea anemones, chitons, snails, crabs, shrimp, horseshoe crabs, hermit crabs, starfish, and brittle stars make good specimens. Avoid the burrowing forms. Sponges, jellyfish, corals, marine worms, and sand dollars should be avoided, since they may die unseen and foul the water. Cautious observation of fish and plants will determine which species will survive well in your situation. It is important to watch the organisms in your aquarium and remove any deceased members of the community immediately. Further information about suitable organisms can be found in the references cited below.

Once the system is operating, care is easy. Each day, a person familiar with the aquarium should check filters and specimens. Dead animals must be removed at once. Add tapwater as often as necessary to keep water at level marked. Do not add salt water, since this will increase the salinity.

Though sea-salts don't disintegrate, specimens will stay healthier with partial water changes at regular intervals. Suggestion: once a month, add a few gallons of new seawater solution after siphoning off the same amount from the tank.

For algae control, scrape tank walls every two weeks.

The above suggestions apply to all marine aquaria. If you live in a Northern latitude and want to keep local cold water species, you will need a refrigeration unit of some description. Instructions for home-made units can be found in reference books on marine aquaria. Ready-made refrigerated aquaria are available and expensive.

If, after reading the above, you are discouraged, take heart. Hundreds of teachers are operating successful in-class marine aquaria. The technical problems can be overcome. If you feel that it is unquestionably "out of your league" and you cannot obtain help from another source, do not completely forsake the idea. A simple aquarium for hermit crabs can be set up for a very few dollars. Solicit donations from students -- all glass aquaria are plentiful. Go to a pet shop and buy a hermit crab or two and get instructions on how to keep them alive. It can be fun! At the very least, set up a freshwater aquarium with goldfish or tropical fish so that you can use a living example when you talk about aquatic organisms. Here is a real opportunity to use all that creativity that got you into teaching in the first place. Good luck!

RECOMMENDED READING

James, Daniel E.	Carolina Marine Aquaria, Carolina Biological Supply Co., 2700 York Road, Burlington, North Carolina 27215, 1974. This booklet is available from the above address and offers valuable assistance as well as information for single organisms or complete kits. 24 pages.
King, John M. and Spotte, Stephen	Marine Aquariums in the Research Laboratory, Aquarium Systems, Inc., 33208 Lakeland Blvd., Eastlake, Ohio 44094, 1974. Describes tank set up and maintenance, as well as offering experiments which can be performed using marine aquaria. Also advertises Instant Ocean products. 39 pages.
Straughan, Robert P.L.	The Salt-Water Aquarium in the Home, 2nd edition, A.S. Barnes and Co., New York, 1970. A comprehensive reference. 360 pages.

BIBLIOGRAPHY OF SELECTED BOOKS ABOUT THE MARINE ENVIRONMENT

The ocean by its very nature lends itself to a multidisciplinary teaching approach. The following list of books related to the marine environment is provided to help you arouse in your students an awareness of the world around them and an awareness of their relationship with and their responsiblity toward their environment. The books were selected to be appropriate for young readers thirteen and older. The list is not intended to be comprehensive, but it does include enough variety to begin a real reading affair with materials dealing with the sea.

The books listed were selected because of their presence on two or more bibliographies of works dealing with the sea. For a more comprehensive, though largely unannotated, list of books available, consult:

> Project COAST. A List of Books on the Marine Environment for Children and Young People. University of Delaware, College of Education; Newark, 19711. 1978. 62 pages.

Amos, William H. The Life of the Seashore. McGraw-Hill, Inc. 1966.

From the publishers of "Our Living World of Nature" series, this colorful marine work is a good introduction for a trip to the coast.

Barbour, John A. In the Wake of the Whale. Crowell Collier Press. 1969.

A readable book that describes the life history of the different whales. It also contains a very good discussion of whaling practices and how they have affected whale populations.

Bascom, Willard N. Waves and Beaches: The Dynamics of the Ocean Surface. Doubleday Anchor Books. 1964.

A straight-forward presentation of waves, tides and how the sea interacts with the land.

Benchley, Nathaniel. Beyond the Mists. Harper and Row Publishers. 1975.

Based on the Norse sagas, this is a fascinating account of the violent and hazardous world of Viking raiders and explorers.

Berrill, N.J. The Life of the Ocean. McGraw-Hill, Inc. 1966.

One of the "Our Living World of Nature" series. Also a colorful introduction to the oceans.

Bonham, Frank. Deepwater Challenge. Thomas Y. Crowell Co. 1963.

A young boy, determined to become the family breadwinner, learns that trying to outwit the sea is a tough and dangerous job.

Brown, Joseph E. Sea's Harvest. Dodd, Mead & Co. 1975.

The story of modern aquaculture with a summary look at the future.

Carson, Rachel L. The Sea Around Us. Oxford University Press. 1961.

Excellent general review of descriptive oceanography, somewhat dated, but a beautifully written book.

Clarke, A.C. The Challenge of the Sea. Holt, Rinehart & Winston, Inc. 1960.

A scholarly discussion of man's exploration and exploitation of the sea's resources with a look at some future possibilities.

Cowen, Roger C. Frontiers of the Sea (revised edition). Doubleday & Co. 1969.

An oceanographic best seller. This revised edition updates the original book to include oceanographic events that took place during the decade of the sixties. The book is written in a lucid and authoritative prose.

Cromie, William J. Exploring the Secrets of the Sea. Prentice-Hall, Inc. 1967.

An enjoyable introduction for the young reader.

Defant, Albert. Ebb and Flow: The Tides of Earth, Air and Water. University of Michigan Press. 1958.

A good introduction to tides.

Engel, Leonard and the editors of Time, Inc. The Sea. Time-Life, Inc. 1969.

An engaging and attractive presentation of the marine environment. The illustrations are magnificent and text is substantial. The photographs are excellent and the drawings are very well done.

Fairbridge, Rhodes W. The Encyclopedia of Oceanography. Reinhold. 1966.

A collection of information which previously was found only in text books and reference works.

Gross, M. Grant. Oceanography. Charles E. Merrill Publishing Company. 1967.

A well done overview of the marine sciences.

Gullion, Edmund A., editor. Uses of the Seas. Prentice Hall International, Inc. 1968.

A background book for American Assemblies on Uses of the Seas discussion groups, but the general reader will find it valuable especially in the areas of national and international law and organization in the sea.

Hardy, Sir Allister. The Open Sea: Its Natural History. Houghton Mifflin Co. 1965.

To quote one reviewer, "This is one of the great books about the sea of our generation. The best introduction to marine biology for the layman that we have."

Hemingway, Ernest. The Old Man and the Sea. Charles Scribner's Sons. 1952.

Classic that explores the mysteries of the sea, the meeting of youth and old age, the glories of a solitary purposeful life, the battle for recognition, and the struggle of the human spirit for survival.

Heyerdahl, Thor. Kon-Tiki. Rand McNally & Co. 1950.

Classic research in the field of cultural migration/transmission. Adventure and history in a text about the influence of the sea on cultural development and world history.

Idyll, C.P. Abyss. Thomas Y. Crowell Co. 1964.

A most interesting treatment of the deep oceans and the creatures that dwell therein.

Idyll, C.P., editor. Exploring the Ocean World. Thomas Y. Crowell Co. 1969.

A history of geographic, oceanographic, and even archeologic studies of the oceans from ancient times to the present; geared to an interested, non-technical audience.

King, Cuchlaine A.M. An Introduction to Oceanography. McGraw Hill Book Co. 1965.

Intended for those without a background in physics, mathematics and biology.

Linklater, E. The Voyage of the Challenger. Doubleday. 1972.

Well written and beautifully illustrated account of the first global oceanographic expedition. An intensely interesting story for those interested in marine science or history.

Lord, Walter. A Night to Remember. Holt, Rinehart & Winston, Inc. 1955. and Bantam Books, Inc. 1955.

Suspenseful story of the Titanic: gallantry, bravery, foolishness, cowardice.

Loti, Pierre (Pseudonym for Biaud, Julien). An Iceland Fisherman. Reprinted by J.M. Dent & Sons. 1961.

Tells of the love of a group of people for the sea, and how the sea influences every aspect of their lives: the superstitions, the faith, and the beauty.

Marx, Wesley. The Frail Ocean. Ballantine Books, Inc. 1967.

A discussion of pollution and related matters.

McCoy, J.J. A Sea of Troubles. Seabury Press. 1975.

Examines the present-day threats to the vast resources of the world's oceans and the political and economic conflicts involved in trying to save the sea from irreversible damage.

Miller, Robert C. The Sea. Random House. 1966.

A well illustrated, general reference of marine topics that treats most aspects of marine science.

Norton, Andre. Sea Siege. Harcourt Brace Jovanovich, Inc. 1957.

Shows effects of an atomic blast on an isolated island. Presents ecological interrelationships and discusses changes in environment and lifestyles.

Ommanney, F.D. The Fishes. Time, Inc. Life Nature Series. 1963.

Like other books in the series, this is well illustrated.

Piccard, Jacques, and Dietz, Robert S. Seven Miles Down, The Story of the Bathyscaphe Trieste. G.P. Putnam's Sons. 1961.

An account of the bathyscaphe and its deepest dive. Good for engendering student interest in oceanography.

Polmar, Norman. Death of the Thresher. Chilton Book Co. 1964.

Documentary account of the loss of a U.S. atomic submarine with its one hundred twenty-nine crewmen.

Rabling, Howard. The Story of the Pacific: Explorers of the Earth's Mightiest Ocean. W.W. Norton & Co. 1965.

An absorbing, well written history of the Pacific from Magellan to the mid-nineteenth century.

Reish, Donald J., editor. Biology of the Oceans. Dickenson Publishing Co., Inc. 1969.

An anthology of biological oceanographic articles giving insight into methods and types of research done by the biologist in the sea.

Ricciuti, Edward R. Killers of the Seas. Walker & Co. 1975.

Fascinating yarns and useful facts about dangerous creatures found in the waters of the world.

Ricketts, Edward F. and Calvin, Jack, rev. by Joel W. Hedgpeth. Between Pacific Tides. 4th edition. Stanford University Press. 1968.

The standard work for West Coast people who are interested in life along the shore.

Scheffer, Victor B. Year of the Whale. Charles Scribner's Sons. 1969.

An excellent dramatization of whale biology.

Smith, Harvey Garrett. The Marlinspike Sailor. John DeGraff, Inc. 1975.

Crafts and projects based on traditional skills of the sea: knots, splices, whippings, rope ladders, lanyards, fenders, mats, grommets, decorations for chests, bags and fittings.

Southward, A.J. Life on the Sea-Shore. Harvard University Press. 1965.

Provides excellent examples of how to study various problems of biology on the sea shore. Recommended for those interested in designing constructive field trip exercises.

Steinbeck, John. The Pearl. Viking Press. 1947.

A poor, superstitious Mexican finds a priceless pearl. With it he wants to buy respect and health for his family. His wife, thinking the pearl is evil, wants him to get rid of it. Many conflicts develop as others try to steal his pearl.

Thorson, Gunnar. Life in the Sea. McGraw Hill Book Co. 1971.

Excellent discussion of marine biology.

Warner, William W. Beautiful Swimmers. Penguin Books. 1977.

A natural history of the blue crab is combined into a study of Chesapeake Bay and of the water men who make a living in the crab's pursuit.

Williamson, W.M., editor. The Eternal Sea: An Anthology of Sea Poetry. Books for Libraries, Inc. 1946.

Twenty-one chapters of poetry arranged by titles such as "The Call of the Sea," "Homeward Bound; Making Port," "Fishermen..."

Yasso, Warren E. Oceanography. Charles E. Merrill Publishing Co. 1967.

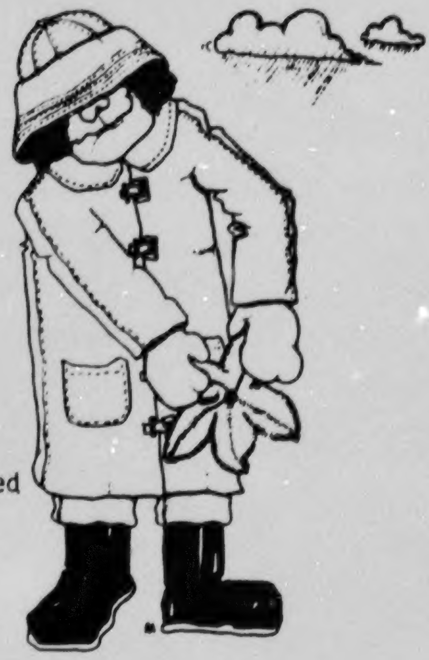
Used in many high schools as a background text.

Yonge, C.M. The Seashore. Collins. 1949.

Although written about British shores, this is a standard little volume which should be on the shelf of all who visit the edge of the sea.

SUCCESSFUL FIELDTRIPPING

Marine Biology and Oceanography is designed as a self-contained curriculum equally appropriate for schools located on the edge of the sea and for schools located inland. As such, the activities included by and large do not require access to the water. If access is available, however, it can and should be utilized to broaden the experience and provide your students with further "hands on" opportunities to become familiar with the marine environment. The following guidelines are presented to help you lead a successful trip to the shoreline.



Proper Rain Gear

GUIDELINE FOR ROCKY INTERTIDAL FIELD TRIPS

The edge of the sea has fascinated man since earliest times. He used the margin to find a source of food and many of his gods were to be found in the sea. He looked to the margin of the sea as a defensive barrier to marauding enemies and as a passageway to trade with other units of society.

Why man is drawn to the sea has been a subject for philosophers, poets and physiologists. That he is drawn to the sea today is the concern of land developers, ecologists and the general citizenry.

Increasing human population, shortened work weeks, increased mobility and popularity of "environmental awareness", all contribute to greater numbers of people examining the magnificent beauty available to the human eye at low tide. The word "oceanography" has captured the imaginations of our citizens, including teachers and their students. The edge of the sea is most accessible to them and field trips are being taken by an ever increasing number of groups and individuals. In too many places the result of this increased utilization of the environment has resulted in the modification of that environment from a veritable jungle to that of a desert.

These guidelines are designed to offer some suggestions to those planning group visits to the shore. Our goals are educational usefulness, environmental protection, safety and esthetic enjoyment. Our concentration is on the rocky shore because of its great abundance and variety of life. Suggestions are in four sections as follows: preparation (Plotting the Course); at the site (All Hands Topside); back in the classroom (Swabbing the Deck); and references. They are in the form of questions the field trip organizer should consider.

PLOTTING THE COURSE

A. - What are your objectives besides getting out of doors?

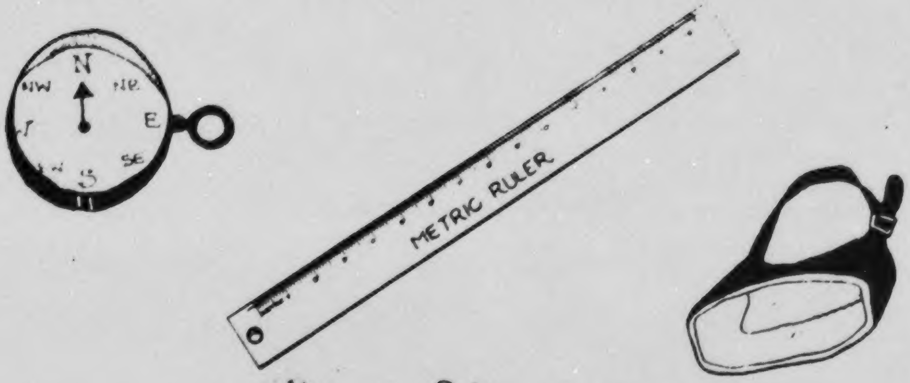
B. - Have you personally visited the site?
- Does the site minimize the inherent dangers?
- By the way, have you checked the tide table for a + 1' tide or lower?
- Have you established transportation and published itinerary?
- Are you familiar with the state's intertidal rules and regulations?

C. - Have you considered teaching aids such as films, slides, resource people, books, bulletin boards?
- Have you established work crews (i.e. 5 - 8 with a captain for each)?
- Does each crew understand its mission?
- Where are you going to get your adult help? Parents? Bus driver? College students? High school students?
- Has acceptable behavior been agreed upon?
- Where is your food cache?
- Would emergency telephone arrangements be useful?

D. - Will everybody have pocket money for snacks, etc?
- Do you know what salt water does to leather shoes?
- Do you know what cold, wet conditions do to one's enthusiasm and attention span?

E. - Why must you return rocks to their original position?
- Do you know that when you crush a sea urchin you may be destroying 10 - 15 years of growing?
- Have you considered that when you remove a six inch square segment of mussel bed you are destroying over 6,000 living creatures?
- Does everyone understand that if you leave the organisms on the beach, the next group will be able to see them?

F. - Do you have a first aid kit?
- Will you have emergency transportation?
- Do you know what barnacles do to naked ankles and sea urchins do to exposed toes?
- Does each crew have a wave watcher and a tide watcher?
- Smooth soles lead to departed souls. WATCH YOUR STEP!

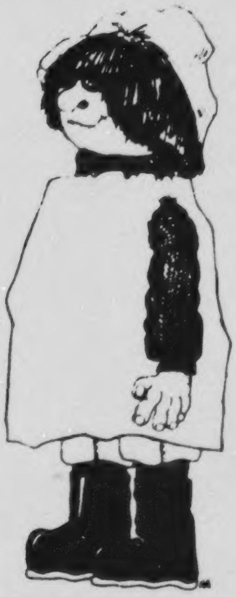


G. Clothing, Supplies and Equipment for Your Trip

Clothing--Proper clothing is a very important consideration for the enjoyment and success of seashore activities. Most trips to the seashore need not be cancelled due to poor weather conditions provided that the participants are properly clothed. Weather conditions at the seashore are highly unpredictable. I have seen sun, wind, rain, and hail all in the same day. As a general rule IT IS BETTER TO OVER DRESS THAN TO UNDER DRESS.

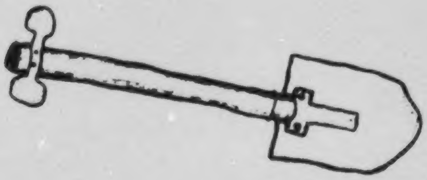
It is essential that clothing be both comfortable and functional. Attention should be paid to the characteristics of different fabrics. The following suggestions are provided as a guide to proper clothing. You will need to add or delete items to fit the general climate of your area.

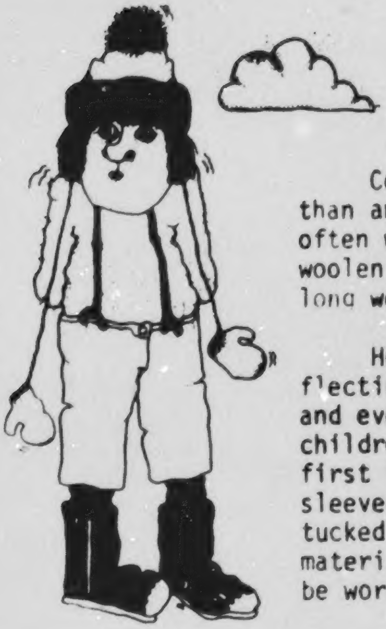
Rain Gear--One of the most important considerations when going to the seashore is how to keep dry. One way to choose the most appropriate gear is to examine what a fisherman wears. A fisherman wears good rubber boots with thick soles, woolen socks, a long nylon or rubberized rain coat with a hood or a fisherman's rain hat, and rubberized pants. A variety of synthetic substitutes can be worn, but it should be emphasized that such items as wind breakers, sweat shirts, and cotton jackets are not substitutes for water proof rain gear.



Emergency Rain Gear

Emergency Rain Gear--No matter how much you emphasize the importance of proper clothing there will always be a number of students and assistants who will show up poorly dressed. It is a good idea to bring along a dozen or so large plastic garbage bags. These bags are great because they can be fashioned into make-shift rain coats, hats, and boots. And get clear bags; they can be used as aquariums or as aids to writing during rainy weather.





Cold Weather Gear--Wools retain warmth more than any other material, even when wet. Fishermen often wear heavy woolen sweaters, woolen mittens, woolen hats that cover the ears, woolen pants, and long woolen or thermal underwear.

Hot Weather Gear--On hot, sunny days the reflection off the water can cause severe sunburns and even sun strokes. This is particularly true of children who are not used to the out-of-doors. On first trips each child should bring along a long sleeved, cotton shirt and a cotton hat that can be tucked into the back pocket. Cotton is an excellent material for any trip to the seashore because it can be worn under wool or under rain gear.

Cold Weather Clothing

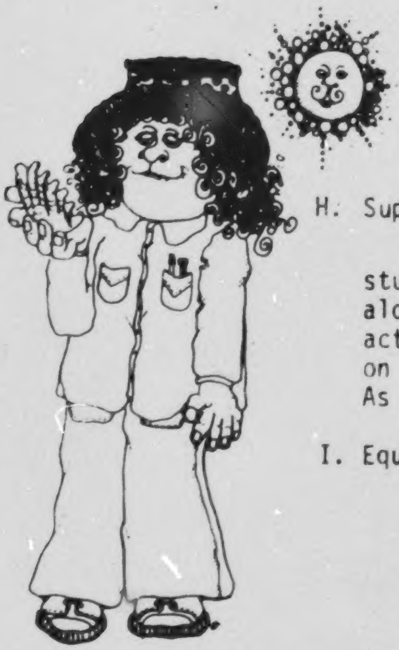
Clothing Check List

Day Trip

rain coat
rain hat
rubber boots
heavy woolen sweater
long sleeved cotton shirt
2 pair socks
2 pair pants

Extended Trip

rain coat
rain hat
rubber boots
rubber pants or woolen pants
heavy woolen sweater
woolen mittens
3 pairs woolen socks
2 pairs cotton socks
2 pairs jeans
2 long sleeved cotton shirts
cotton hat
long woolen underwear



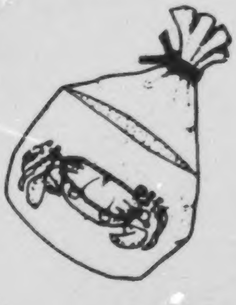
Hot Weather Clothing

H. Supplies and Equipment

In addition to the supplies that each individual student is required to bring you will want to bring along some extra equipment and supplies for class activities. The equipment that you choose depends on the length and the specific purpose of your trips. As a general rule travel as light as possible.

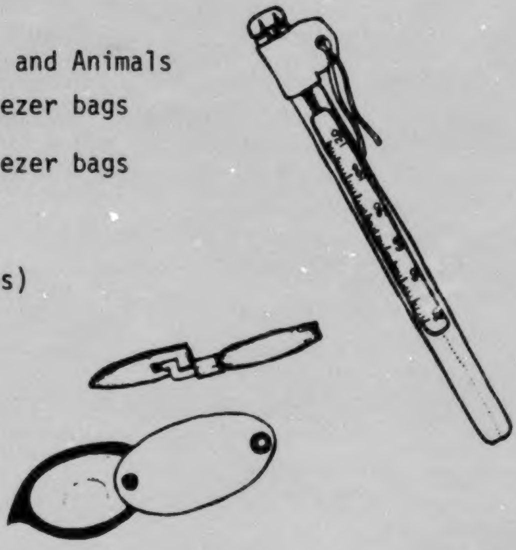
I. Equipment for Collecting Plants and Animals:

wide mouthed gallon jars
plastic pails
shovel with short handle
kitchen sieves
small nets
putty knife
pocket knife



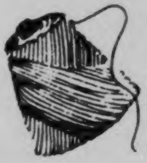
J. Equipment for Observing Plants and Animals

2 or 3 dozen clear plastic freezer bags
rubber bands or bag twisters
1 dozen ½ gallon or gallon freezer bags
wide mouthed jars
clear plastic aquariums
magnifying glasses
microscopes (for extended trips)
binoculars
face masks



K. Equipment for Measuring Data

compasses
thermometers
stop watch
metric stick or tape
string
baby bottle with measuring scale



L. Equipment for Recording Data

field notebooks with pencil attached
tape recorders
cameras

M. Additional Equipment

local field guides
extra spiral notebooks
extra pencils
newspaper
toilet paper
first aid kit
large sketch pad
water color sets
pastels
charcoal

Sitting Pad.

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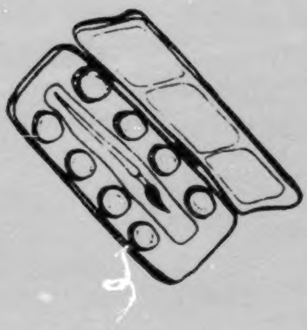
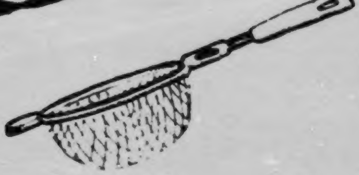




ALL HANDS TOPSIDE

Are all present or accounted for? What are you going to do?
Have you defined the physical boundaries for exploration?
What is the direction and pattern of the waves?
Are crews assembled with their equipment? Does each member understand his duties?

A. Have you scheduled a familiarization time for when you first hit the beach? What kinds of rocks are present? What birds are evident? Is there a lot of driftwood? How steep is the beach? What is the surf like?

B. What specific program will each crew carry out?

I. Observing?

Are there vertical bands of organisms? If so, how many are there?
How many different kinds of creatures are found under rocks?
Did you return rocks to original position?
How does a sea anemone feed? (Harvest one mussel for feeding experiments. How does a crab eat?
How does a limpet react to juice squeezed from a starfish?
Is distribution of organisms different on wave side of rock compared to lee?

II. Classifying?

How many kinds of algae can be found?
How do snail shell structures differ in sculpturing, hole size?
How many different ways do algae hold onto rocks?
How many different species of crabs can be found?
How do the various barnacles differ structurally?
How do color patterns and sculpturing differ among limpet shells?
How many different kinds of animals and plants can be found in one tide pool?

III. Measuring?

What is the temperature of a high tidepool? A low tidepool? The ocean? The air?
Among limpets of the higher rocks, what range of shell lengths are there?
How long does it take a sea anemone to swallow a bit of food?
How long does it take various starfish to turn over when placed on their topside?
How wide are the bands of organisms on rocks (if they are seen)?
If you use a squared wire coat hanger for area reference, what is the density of creatures at different levels of the tidal zone?
If you find barnacles feeding in a tidepool, how many times a minute do they rake their feathery feet through the water?

SWABBING THE DECK

Will there be oral presentations, analyzing what each crew did?
Will you share your experiences with other classes in the building?
Will there be formal evaluation?
Will you integrate the field experience with other experiences?
Will there be a parent's night to show them what you did?
Will local news media be invited?
Have you or the students written thank you letters to those who helped you?
Have you written thank you letters to the appropriate people if there was necessary first aid given?
Do you have a file on what you will change the next time you go to the intertidal?

SAFETY - SPECIAL PRECAUTIONS

Any teacher should be aware of the potential dangers on the beach. Drift logs, steep and crumbly trails, treacherous waves, and incoming tides all must occupy a leader's attention.

1. Take only a group of manageable size to the beach. If your group is larger than 30 students, be sure to include an adequate number of properly briefed chaperones, to help keep an eye on energetic students. One adult for every 10 students is a good ratio.
2. Be sure the students are dressed properly for the trip. Long pants and tennis shoes (or rubber boots) are musts. Warm jackets are a good idea, as it is almost always chilly at the beach.
3. Be sure a first aid kit is available for the minor cuts and abrasions that are likely to occur.
4. Visit the site of the field trip before the trip date, to become familiar with the beach area the group will visit.
5. Study the tidetable; plan to arrive at the beach *an hour before low tide*. It is safer to be on the beach with an outgoing tide.
6. Check weather conditions before starting the trip; a stormy winter beach, with waves pounding, is not a place to take a group of students. Seas eight feet and above are considered rough; be especially careful to keep a good distance from the water line if you are on the beach under these conditions.
7. Playing and exploring around drift logs are sources of enjoyment, *but stay away from those near the water.* Logs are easily moved by only a small amount of water, and every year beachcombers are crushed by rolling logs.
8. Never build a fire in the drift logs. It can spread through the driftwood area.
9. Trails to the beach are often slippery and steep. On dangerous trails, station chaperones at intervals for an orderly descent to the beach.
10. While on the beach, always be on the alert for extra large "sneaker waves".

11. Don't let the incoming tide trap you or any of the group on a rock or ledge. Assign one of the chaperones to a "wave and tide" watch while on the beach.
12. Rock pinnacles are a challenge to most students, but they are steep and dangerous. Many are bird refuges,and it is against the law to disturb the birds.
13. Rip currents are a reality. Never allow students to wade or swim while on the field trip. Strong currents run out to sea and can carry inexperienced swimmers with them.
14. Assign the students to a buddy system while at the beach.

CONSERVATION

Rocky tidepool areas are limited in size; thousands of students visiting these areas during the spring low tide series can cause real problems of overuse. Stress conservation practices to the students before you leave the classroom.

1. Squelch the "save it and take it home" impulse. The replacement rate of some of the animals is not very rapid, and your collecting may deprive other students from ever seeing the more unusual species.
2. It is lawful to collect for a classroom aquarium or other selected educational purposes. Check the current angling regulations for information about tidepool animals. Or check with the Department of Fish and Wildlife for information about regulations and collecting permits.
3. When students pick up rocks that reveal hidden animals, be sure they return the rocks. Tubeworms, sponges, and other sessile animals live there for protection; they will die if left exposed.
4. If students pick up animals and examine them, they must return these to the spot where they found them. Some animals have specific feeding requirements, and they live at specific tidal heights. Moving them to another part of the beach can kill them just as surely as removing them *from* the beach.
5. Soft-soled rubber boots or tennis shoes are less damaging to the animals than heavy, hard-soled hiking boots. Selection of proper footgear can be another conservation measure.

THE ORIGIN OF THE OCEAN BASINS:
THEORY OF PLATE TECTONICS

TEACHER BACKGROUND - Before the Gray Whale and Puzzling Pieces

"Before the Gray Whale" is the first of several activities dealing with marine geology. Our view of the earth and the processes that have shaped its surface have undergone dramatic changes in the past two decades. "Before the Gray Whale" gives your students an introduction to the concept of plate tectonics. Plate tectonics gives new life to the old ideas of continental drift and explains the distribution of many large scale geologic features and zones of activity. The broad outlines of the theory of plate tectonics are now widely accepted. Essentially, the earth's surface is comprised of several large plates of crustal material. These plates are in motion relative to one another. The plates appear to be moving apart from each other along the mid-ocean ridges. The ridges are also the location of the formation of new ocean floor material. Where the plates collide, one plate (usually an oceanic plate) dives beneath another (usually a continental plate). As the plate continues to descend, the rocks which form it become heated and eventually melt forming new mantle material. Narrow belts of mountains, volcanic activity and earthquakes occur at these plate boundaries. While agreement on the mechanism causing the movement is not universal, it appears that slow moving convection currents within the mantle provide at least some of the force required to move the crustal plates. An excellent historical perspective of the theory and a review of the current state of the art may be found in the Scientific American publication:

Continents Adrift and Continents Aground with introductions
by J. Tuzo Wilson. 1976. W.H. Freeman and Company.
San Francisco, California 230 pages.

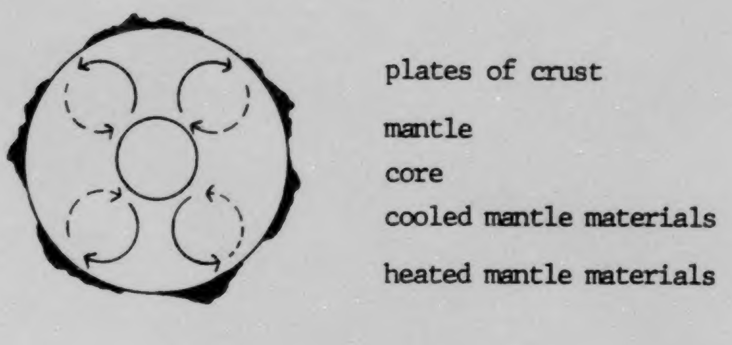
Duplicate the text pages. One set is recommended per student. Note that the text questions immediately follow the section to which they pertain. This approach serves to reinforce and/or expand the topic in the most logical location. This activity lends itself well to completion by individual students as a homework or in-class assignment. Either way, plan to allow time for a class discussion of the materials. This topic should be supplemented with films and graphics.

If you are not familiar with the material, consider skimming some of the articles found in the previously cited publication. Current introductory college-level texts also provide a good overview of the topic. Remember that this activity is an introduction. Many of the concepts introduced will be covered in more detail in subsequent activities. "Puzzling Pieces" reinforces the new vocabulary found in "Before the Gray Whale".

If you have not already done so, now is the time to become familiar with the organization of this guide. Each major division (for example, "Beneath the Seas") has an introductory reading which sets the background for that section. The reading includes text questions for your students to answer as they read. The major divisions also include student activities and laboratory exercises. Each activity or exercise has a separate "Teacher Background" section. The readings and activities for each section increase in difficulty as you progress within the section. The differences in the difficulty of the articles will allow you to provide materials to fulfill the needs of the variety of students typically found within a single class. The range of materials provided can help you to individualize your instruction. There are several ways to teach the materials included in this guide. Two possible approaches are included here by way of suggestion. Each reading or activity can be presented, in the order listed in the index, to the whole class simultaneously. You can decide which of the advanced activities to include by your knowledge of the class or by stopping when the activity just completed was obviously too difficult for the majority of your students. An alternative approach involves the preparation of a file of class sets of the student readings and activities presented. Each student is given a checklist of the activities and readings in the file. The students may work on any activity at any time. Prior to employing this approach, you will need to advise your class of their responsibilities and of the grading procedure to be followed. For example, you may wish to have a list of the assignments which must be satisfactorily completed to earn a C grade, a B grade or an A grade. From the list of assignments you could easily develop a contract which your students would sign indicating the grade they intend to earn. A deadline for completion of the unit must be posted. The materials required for the activities and laboratory exercises must be accessible to the students. This approach requires more advance planning and advanced duplication of the materials than the first approach mentioned. It has the advantage of placing an increased amount of responsibility for completion upon the student. Other approaches are also possible. Whichever approach you select, it is important that you generate enthusiasm for study about the marine environment before you begin and during the course of study.

Key

1., 2.



3,4. The answers depend upon your location but can be readily determined by reference to the map included in the text.

5. $100{,}000{,}000 \text{ years} \times \frac{15 \text{ cm}}{\text{year}} = 1{,}500{,}000{,}000 \text{ cm wide}$

6. a. $\frac{1{,}500{,}000{,}000\text{cm}}{100 \text{ cm/m}} = 15{,}000{,}000 \text{ meters wide}$

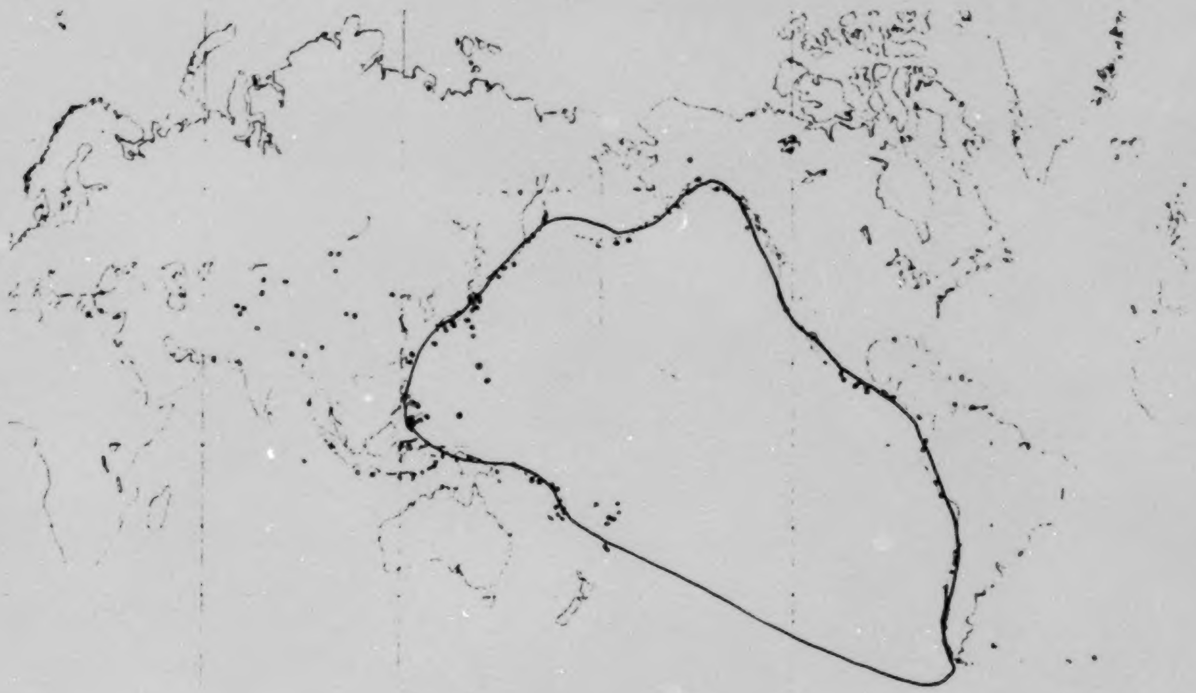
b. $\frac{15{,}000{,}000\text{m}}{1000\text{m/km}} = 15{,}000 \text{ kilometers wide}$

c. The actual width of the Pacific Ocean basin and the width calculated in part b. are the same.

d. The information above indicates that sea floor spreading alone could indeed account for the size of the Pacific basin.

7. As it sinks into the hot mantle, the crust is heated. The farther it descends the hotter it becomes until it finally becomes molten mantle material itself.

8. The "Ring of Fire" is shown below:



9. The answer depends upon your location but, once again, it may be readily determined by reference to the map included in the text.

KEY WORDS

basin
circumstantial
coincidence
continent
continental drift
convection current
core
crust

fossil
geology
hypothesis
mantle
meteorologist
molten
Pangea
plates

Ring of Fire
sediment
static
submarine ridges
theory
topography
trench
volcanic

35 T	56 H	5 E		28 S	44 U	23 R	54 F	2 A	7 C	11 E		8 O	54 F		13 T	56 H	22 E		27 E	6 A	33 R	20 T	60 H	
14 I	42 S		17 M	15 O	10 V	24 I	3 N	4 G		34 I	9 N		21 L	18 A	52 R	4 G	41 E		1 P	31 L	32 A	47 T	22 E	43 S
55 T	56 H	61 E		29 P	38 L	39 A	40 T	61 E	62 S		17 M	30 O	65 V	70 E		69 A	37 P	69 A	52 R	59 T		69 A	73 T	
73 T	56 H	61 E		17 M	48 I	25 D		49 O	12 C	61 E	69 A	16 N		52 R	53 I	45 D	26 G	61 E	64 S		69 A	19 N	51 D	
54 F	58 O	52 R	17 M		51 D	61 E	61 E	57 P		73 T	52 R	61 E	50 N	12 C	74 H	61 E	71 S		72 W	74 H	61 E	52 R	61 E	
73 T	74 H	61 E	36 Y		46 C	66 O	67 L	67 L	63 I	51 D	61 E													

KEY:

PUZZLING PLATES

a. The super-continent which existed 200 million years ago is called
P A N G E A .
1 2 3 4 5 6

b. The plates of crustal material are moved by C O N V E C T I O N currents.
7 8 9 10 11 12 13 14 15 16

c. The layer of the earth between the crust and the core is called the
M A N T L E .
17 18 19 20 21 22

d. The giant plates of the earth's crust are moving apart at the mid-ocean
R I D G E S .
23 24 25 26 27 28

e. An important piece of evidence supporting the theory of continental drift comes from readings of the magnetic P O L A R I T Y of rocks.
29 30 31 32 33 34 35 36

f. Where P L A T E S meet, one tips down and slides beneath the other.
37 38 39 40 41 42

g. Plate collision is also called S U B D U C T I O N .
43 44 __ 45 __ 46 47 48 49 50

h. The idea that the land masses move is sometimes called the theory of continental D R I F T .
51 52 53 54 55

i. Alfred Wegener set forth the testable statement or H Y P O T H E S I S .
56 __ 57 58 59 60 61 62 63 64

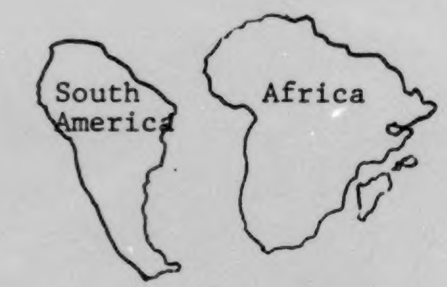
j. The "Ring of Fire" is made up of many V O L C A N O E S .
65 66 67 68 69 __ __ 70 71

k. The earth is an unstable ball covered W I T H sections of crust.
72 __ 73 74

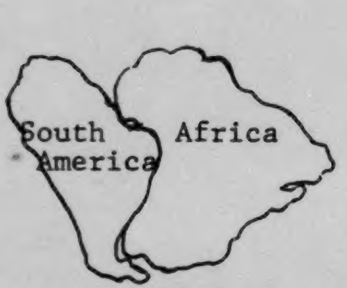
BEFORE THE GRAY WHALE

Before there was the whale, the earth was. What forces shape our planet? Has the earth always looked the way it does today? In the early 1900's most scientists would have said "Yes, the earth's surface has looked the same throughout its history". Have the ocean basins and the continents always been where we find them today?

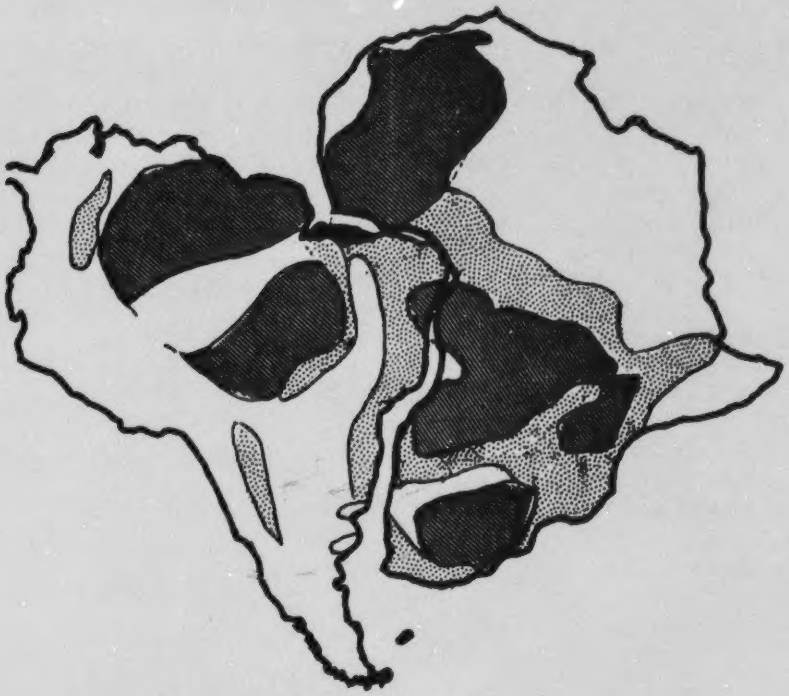
What observations made people question the theory of an unchanging earth? On the map below, look at the east coast of South America and at the west coast of Africa. It does not take much imagination to see that the two coasts look very much like mirror images.



Perhaps we can place them together like this:



An interesting coincidence? Perhaps. Other evidence began to appear. Distinctive rock formations which suddenly end at the continental margin (edge) of Africa, suddenly start at the continental margin of South America.



Similar Rock Formations in South America and Africa

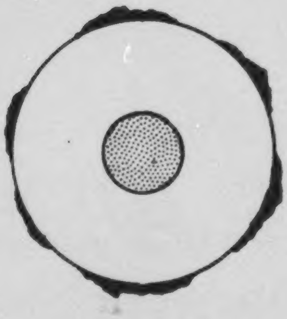
Similar or identical plants and animals were found in the fossil records of distant continents. Had these animals crossed from one continent to another on land bridges which later disappeared? The idea of a land bridge sinking seemed unlikely. Mesosaurus was a small reptile that lived about 270 million years ago. Its fossils are found in Brazil on the South American continent and in South Africa on the continent of Africa and nowhere else in the world.

The earth's topography or shape seemed to show that the surface of the earth was made up of two materials. One surface or crust material was heavier than the other. This observation also failed to fit into a picture of unchanging continents. Unchanging continents would have a single layer crust.

If the observations do not fit the theory, perhaps the theory needs to be discarded or modified. What theory could explain all of the above observations?

In 1912, Alfred Wegener set forth the hypothesis that the continents were in motion. This theory was to start a debate that would continue for over half a century. The continents are moving. Much of the proof for this theory of continental drift comes from the oceans.

It now appears that our planet Earth is an unstable ball. The surface is covered with moving sections of crust called plates. These plates float over the earth's mantle, a layer of molten rock. The molten rock flows in slow-moving circular streams known as convection currents. Below the mantle, the earth's core acts like a giant burner. The core superheats the mantle material and forces it to rise just as hot liquids rise.

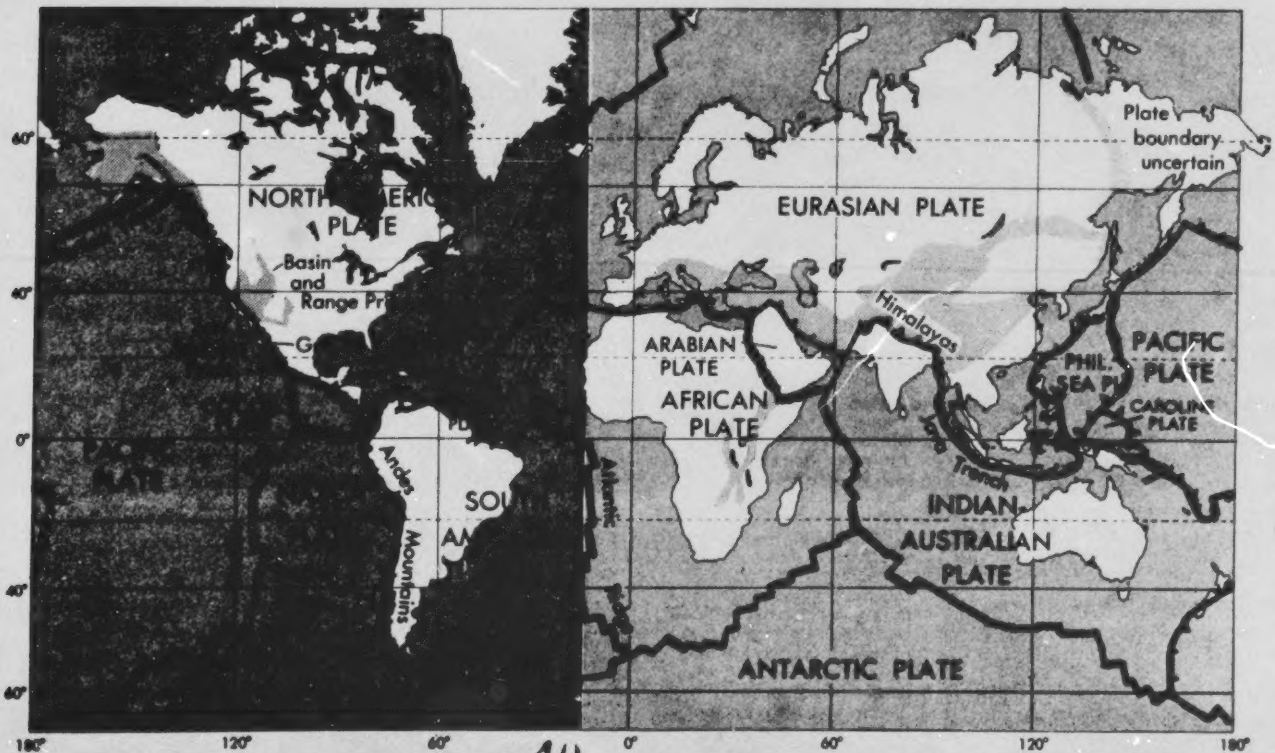


1. The drawing above shows a cross section of the earth. Label the

    a) plates of the crust
    b) mantle
    c) core

2. Hot liquids tend to rise, while cold ones sink. On the drawing above, use a solid arrow to show the direction of movement of heated mantle materials and a dotted arrow to show the movement of cooled mantle materials

There are seven very large plates and a dozen or more small plates moving over the mantle. The figure below shows the major plates.


NORTH AMERIC
PLATE
Basin and Range Pr
G
Andes
Mountains
SOU
AM
Atlantic
Ridge
EURASIAN PLATE
Plate boundary uncertain
ARABIAN PLATE
AFRICAN PLATE
Himalayas
Java Trench
PHIL. SEA PL
PACIFIC PLATE
CAROLINE PLATE
INDIAN-AUSTRALIAN PLATE
ANTARCTIC PLATE
60°
40°
0°
40°
60°
180°
120°
60°
0°
60°
120°
180°

3. On which plate do you live?

4. Do you live near the edge or the middle of the plate?

All of the plates are moving relative to all others. Some plates are moving apart, some are colliding. Plates are pushing away from each other along a system of great submarine ridges in the world's oceans. The rising molten rock from the mantle wells up into the gap helping to push the plates apart. Some of the mantle material oozes down the sides of the ridge and forms new ocean floor.

5. The convection currents carry the plates over the surface at the rate of from two to 15 centimeters (one to six inches) per year. The age of the Pacific ocean floor is estimated at 100 million (100,000,000) years. If the maximum rate of movement (15 cm/year) occurred over this period how wide would the Pacific basin be in centimeters? Show your work.

6. Scientists use centimeters to measure short distances and kilometers to measure long distances. There are one hundred centimeters in a meter and one thousand meters in a kilometer.

   a. Divide the width of the Pacific basin in centimeters by 100 to find its width in meters.

   $\frac{\_\_\_\_\_\_\_\_\_\_\_\_\text{cm}}{100}$ = ____________meters wide.

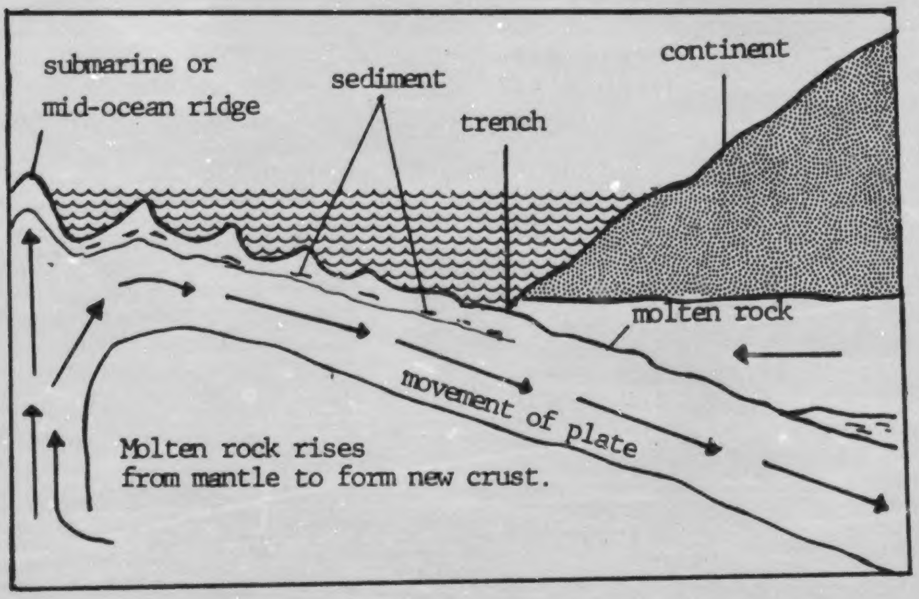
   b. Divide the width of the Pacific basin in meters by 1000 to find its width in kilometers.

   $\frac{\_\_\_\_\_\_\_\_\_\_\_\_\text{m}}{1000}$ = ____________kilometers wide

c. The actual width of the Pacific ocean basin is about 14,000 kilometers. How does the actual width compare with your calculated width from b. above?

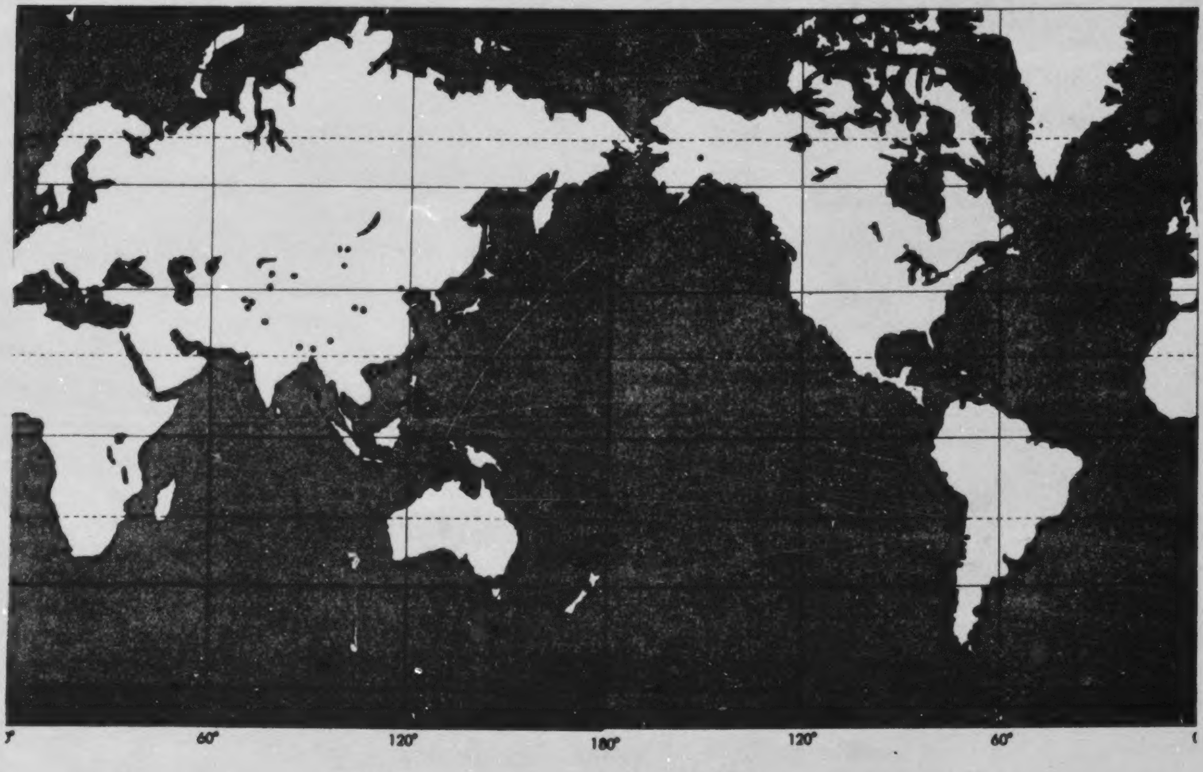
d. Could sea floor spreading alone account for the size of the Pacific basin?

Evidence seems to indicate that the amount of crust has remained the same over very long periods of time. If this is true, the formation of new crust must mean that crust is being destroyed somewhere else. Where does this older crust go? A study of colliding plates gives us the answer. Where plates meet, one tips down and slides beneath the other. The plate sliding beneath has its ocean floor sediment scraped off by the over-riding plate. This scraping forms the deep ocean trenchs we find located off of volcanic coasts.


submarine or
mid-ocean ridge
sediment
trench
continent
molten rock
movement of plate
Molten rock rises
from mantle to form new crust.

7. What is likely to happen to the crust as it sinks into the hot mantle?

Earth scientists have mapped many of the areas where crust is being returned to the mantle to be re-melted. The deepest trenches and some of the most active areas occur along the "Ring of Fire". The "Ring of Fire" is the surrounding plate boundaries of the Pacific. Volcanic and earthquake activity is frequent in the "Ring of Fire."



8. The map above shows the location of earthquakes of magnitude 8.0 and higher, 1897-1976. Connect the Pacific basin earthquakes to form the "Ring of Fire".

9. Use this map and the map of the major plates to determine if you live closest to a ridge or to an area of plate collision (subduction). Are you closest to a ridge or to an area of subduction?

How does this theory of moving plates account for the similar coast lines of South America and Africa? How does it account for identical fossils and geological formations found on distant continents? Geologists and oceanographers have traced the plate movement back 200 million years. They conclude that the present continents formed one large super-continent called Pangea. As the continent tore apart, the similar edges moved apart. Unique geologic and fossil formations moved apart with the continents.

This gradual process of plate movement forms new ocean floors. It destroys old ocean floors and formed the surface of the world as we see it today. The movements of the earth's crustal plates will create yet another, entirely different global design of continents and oceans.

PUZZLING PLATES

Directions:

In order to solve this puzzle you have to fill in the letters of as many words as you can in the spaces alongside the clues given below. When you have written in a word over the dashes, each letter is then moved to the box above which has the corresponding number When all the boxes have letters, you will have a complete scientific statement. Guessing missing letters of incomplete words in the boxes will provide additional clues for unsolved words below.

The first one is done for you. Letter e is partly completed. Move each letter to the box in the puzzle which has the corresponding number. Now. . . . .

GO ON TO NEXT PAGE

35	56	5 E	▨	28	44	23	54	2 A	7	11	▨	8	54	▨	13	56	22	▨	27	6 A	33	20	60	▨
14	42	▨	17	15	10	24	3 N	4 G	▨	34	9	▨	21	18	52	4	41	▨	1 P	31	32	47	22	43
55	56	61	▨	29	38	39	40	61	62	▨	17	30	65	70	▨	69	37	69	52	59	▨	69	73	▨
73	56	61	▨	17	48	25	▨	49	12	61	69	16	▨	52	53	45	26	61	64	▨	69	19	51	▨
54	58	52	17	▨	51	61	61	57	▨	73	52	61	50	12	74	61	71	▨	72	74	61	52	61	▨
73	74	61	36	▨	46	66	67	67	63	51	61	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨

a. The super-continent which existed 200 million years ago is called
P A N G E A.
1 2 3 4 5 6

b. The plates of crustal material are moved by 7 8 9 10 11 12 13 14 15 16 currents.

c. The layer of the earth between the crust and the core is called the
17 18 19 20 21 22.

d. The giant plates of the earth's crust are moving apart at the mid-ocean
23 24 25 26 27 28.

e. An important piece of evidence supporting the theory of continental drift comes from readings of the magnetic P O L A R I T Y of rocks.
29 30 31 32 33 34 35 36

f. Where 37 38 39 40 41 42 meet, one tips down and slides beneath the other.

g. Plate collision is also called 43 44 — 45 — 46 47 48 49 50.

h. The idea that the land masses move is sometimes called the theory of continental 51 52 53 54 55.

i. Alfred Wegener set forth the testable statement or 56 — 57 58 59 60 61 62 63.

j. The "Ring of Fire" is made up of many 65 66 67 68 69 — — 70 71.

k. The earth is an unstable ball covered 72 — 73 74 sections of crust.

TEACHER BACKGROUND - The First Piece of Evidence

"The First Piece of Evidence" is the first of several activities designed to trace the observations which led to the formulation of the hypothesis of continental drift. As early as 1650, writers were commenting on the similarities of the coastlines of eastern South America and western Africa. In this activity your students will have an opportunity to reconstruct the super-continent, Pangea, which is thought to have been the origin of the continents we now see.

Duplicate the activity pages. One set is recommended per student. This activity lends itself well to completion by individual students or by pairs of students. Provide sufficient pairs of scissors to prevent long waits by individuals or groups. Library paste or glue sticks provide quick-drying adhesives. Rubber cement allows the continents to be removed and replaced. Encourage independent work by noting that we can't give "right answers", we can only give "best" estimates" based upon the information we presently have. Plan to discuss the "Analysis and Interpretation" questions upon completion of the activity. Display the finished maps on a bulletin board. The display will enable different classes to compare their maps and it will engender considerable curiosity among other classes. The curiosity is healthy for your program.

KEY

1. a. While the answer depends upon the observations, it is unlikely that all of the maps are identical.

   b. Additional information that could help resolve differences includes maps of geologic deposits that abruptly end at one continental margin and abruptly start at another, identical or similar fossil records, and, unique geologic formations that span separate continents.

2. The continental shelf generally seems to be the best representation of the ancient lines of attachment. (i.e. There is less overlap and are fewer "holes" if the continental shelf is used).

3. The spaces left between other continents may be a result of smaller breaks and differential movement. Pieces of the larger continents may have broken off and moved away leaving a hole in one area and possibly causing an overlap in another. It is also possible that the actual breaking up of the supercontinent caused the destruction of some of the margin. Your students may have other ideas. Discuss their hypotheses and help them to decide what types of information are required to prove or disprove their ideas.

4. The evidence gained from piecing together the continents is purely circumstantial and is not sufficient to convince serious scientists that continental movement occurred. The information is, however, intriguing enough to interest scientists in pursuing other paths to obtain additional information ot establish or refute the theory of continental movement.

KEY WORDS

continental shelf
crust
global projection
observation
Pangea
plate tectonics
theory

THE FIRST PIECE OF EVIDENCE

The first observation leading to the theory of plate tectonics came from the similarities in the coast-lines on each side of the Atlantic ocean. Oceanographers think, that the seven continents we now see were formed from one large super-continent. This super contiment, called Pangea, existed 200 million years ago. What might Pangea have looked like? In this activity you will arrange the present continents into your own version of Pangea.

Materials:

world map or globe (large for reference)
world map 8½" x 11"
scissors
paste or tape
global projection without continents

Procedure:

1. Observe the world map or globe and note the shapes of the Atlantic coast lines of the continents.
2. Obtain an 8½" x 11" world map. Notice that the continents have a rim around them. The rims represent the continental shelves.

3. Cut out the continents and arrange them to form a supercontinent in a manner that seems logical to you. Choose either sea level or the continental shelf edge to cut along.
4. When you have an arrangement that makes sense to you, glue or tape it to the global projection without continents.

Analysis and Interpretation

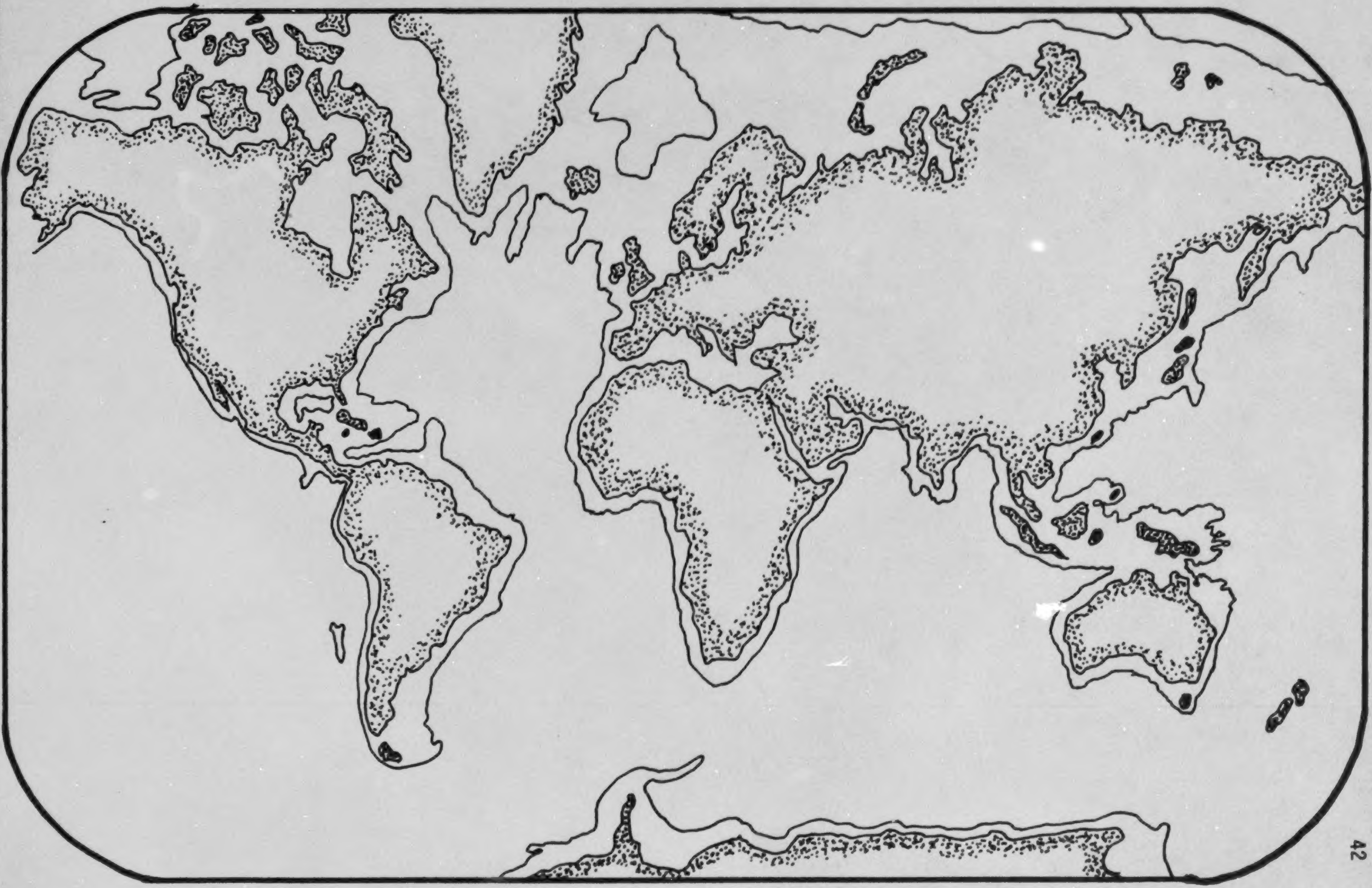
1. Compare your finished map of Pangea with those of others in your class.
   a. Are all of the maps identical?

   b. If there are differences, what might be one additional piece of information you could obtain to settle the differences?

2. Which border, the continental shelf or sea level, seems to be the best representation of the ancient lines of attachment?

3. In aligning the continents, sometimes there is space left between them. For example, the Gulf of Mexico might be such a space. Some geologists think that Central America was once joined to North America along the boundaries of the present Gulf of Mexico. What might account for the spaces left between other continents?

4. Would you say that the information gained from piecing together the continents is sufficient to convince scientists that continental movement occurred? Please explain your answer.



TEACHER BACKGROUND - The Plot Thickens

The study of paleomagnetic readings (the magnetization found within rocks) provided the evidence needed to convince most scientists that the continents had been, and indeed are, in motion. The research which revealed the importance of these paleomagnetic readings is a classic detective story. The evidence provided a major breakthrough and enabled earth scientists to bring together in a cohesive theory many seemingly disparate pieces of evidence. In this activity, your students will have an opportunity to do some of their own paleomagnetic detective work.

Duplicate the activity pages. One set per student is recommended. "The Plot Thickens" may be completed as an individual homework assignment or as an in-class assignment. It may also be completed by pairs of students. Both techniques have merit and the method you choose should be the one that best serves the needs of your particular class. Use yellow high-lighter or orange felt pens to color in the north oriented domains. These colors permit your students to see the arrows through the color. You can obtain the same result by light shading with a pencil. It is helpful to be able to see the arrows through the shading because it allows a ready check of accuracy. Allow time for a discussion of the concepts involved in this activity and to provide answers for the "Analysis and Interpretation" questions.

Text Questions

1. The ~~oldest~~/youngest rocks are closest to the mid-ocean ridge.

Analysis and Interpretation

1.,2. See accompanying Magnetometer readings key.

3. a. This question requires a value judgement by your students. As such, there is no right or wrong answer. Historically, the evidence was sufficient to convince some scientists, not sufficient to convince others. This question should serve as a springboard for a discussion of the acceptance of new ideas by the scientific (or any) community. People, including scientists, find it very difficult to abandon old beliefs

even in the face of large amounts of evidence showing that their current ideas are not valid. It takes an overwhelming amount of evidence to convince scientists to change their outlook on fundamental matters. It has been said, in fact, that scientists never do change their minds. They just die off and the new generation accepts the new ideas. There may be some truth in this theory.

b. Yes, the evidence becomes more convincing when you add information about the shapes of the continents and the similarities of plants, animals, and rock formations from distant continents. The more information and the greater the number of sources of origin of the information the more difficult it becomes for people not to accept a theory.

KEY WORDS

anomalies
compass
continental drift
crustal plate
deposition
hypothesis
lava
magnetic field
magnetite crystals
magnetize
magnetometer
mid-ocean ridges
molten
paleomagnetic readings
parallel
polarity
sedimentation

MAGNETOMETER READINGS IN THE NORTH ATLANTIC 30°W. Long. 64°N. Lat.

☐ = 1 Kilometer ʌ = North Oriented Domains v = South Oriented Domains

v	v	ʌ	ʌ	ʌ	ʌ	v	ʌ	v	ʌ	ʌ	v	v	v	v	ʌ	ʌ	v	v	v	v	ʌ	ʌ	v	ʌ	v	ʌ	ʌ	ʌ	ʌ	v	v	v	ʌ	ʌ
v	v	ʌ	ʌ	ʌ	ʌ	v	ʌ	v	ʌ	ʌ	v	v	v	v	ʌ	ʌ	v	v	v	v	ʌ	ʌ	v	ʌ	v	ʌ	ʌ	ʌ	ʌ	v	v	v	ʌ	ʌ
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Shade in North arrows and locate the mid-ocean ridge. ▲ Mid-Ocean Ridge Oldest Rocks ▲

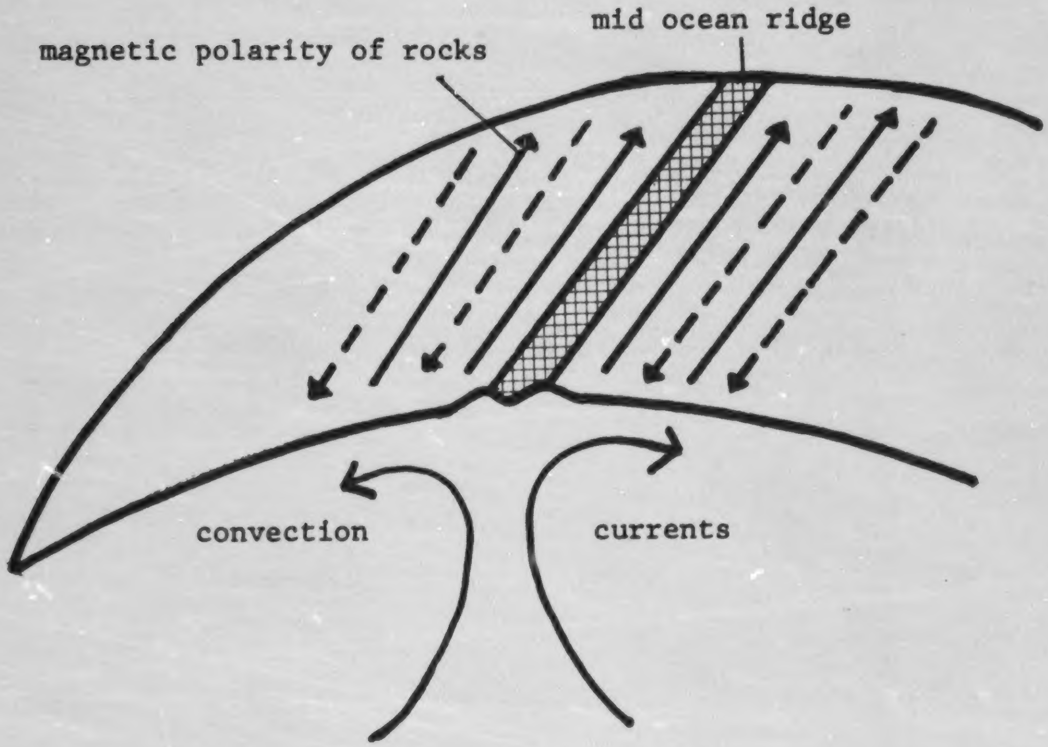
TEACHER KEY

THE PLOT THICKENS

Similar coast lines and similar plants and animals in the fossil record of distant continents were interesting. Interesting but not enough evidence for most geologists to accept the idea of continental drift. For the first half of this century, the hypothesis of continental drift was not accepted by scientists. In the 1960's new evidence came to light.

Rocks can be weakly magnetized at the time of formation - during cooling in the case of lavas and during deposition in the case of sediments. Magnetite crystals in these rocks act like tiny compasses. Rocks formed today show crystals which point north. We say that the magnetic polarity of the crystals is aligned with the direction of the earth's magnetic field at the place and time where the rocks formed. Measurements of these polarity directions show that many rocks are now in places other than where they were formed. This information suggests that the rocks have been moved to their present positions.

Study of these paleomagnetic readings provides additional evidence for the theory of crustal plate movement. Scientists believe that molten material surfaces at the mid oceanic ridges and forms new ocean bottoms. The rock formed in these ridges shows the magnetic polarity occurring when and where they are formed. Other geologic evidence points to the fact that the north pole has not always been in its present position. If this is true, the rocks on each side of the ridge should show parallel patterns of magnetic shifts. The following diagram shows the pattern.


magnetic polarity of rocks
mid ocean ridge
convection
currents

1. The oldest / youngest rocks are closest to the mid-ocean ridge. (Circle the correct answer).

In the following activity you will have an opportunity to use paleomagnetic readings to locate the mid-Atlantic ridge.

Materials:

magnetometer readings sheet

pencil or felt tip marker

Procedure:

1. Obtain a magnetometer readings sheet. A magnetometer is the instrument used to collect paleomagnetic readings.
2. Use your pencil or felt tip to shade in the North arrows.

Analysis and Interpretation:

1. On your sheet, locate the mid-Atlantic ridge and place a circle around it. (Hint: look at the diagram on the preceeding page).
2. Place an X where the oldest rocks are found.
3. a. Would you say that the information gained from the investigation of sea floor spreading is sufficient to convince scientists that continental movement occurred?

   b. Does the evidence become more convincing when you add information about the shapes of the continents and the similarities of plants, animals and rock formations in distant continents?

MAGNETOMETER READINGS IN THE NORTH ATLANTIC **30° W. Long. 64° N. Lat.**

☐ = 1 Kilometer ʌ = North Oriented Domains v = South Oriented Domains

50

v	v	ʌ	ʌ	ʌ	ʌ	v	ʌ	v	ʌ	ʌ	v	v	v	v	ʌ	ʌ	v	v	v	v	ʌ	ʌ	v	ʌ	v	ʌ	ʌ	ʌ	ʌ	v	v	v	ʌ	ʌ
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Name ____________

Date ____________ Period ____________

Shade in North arrows and locate the mid-ocean ridge.

TEACHER BACKGROUND - The Force

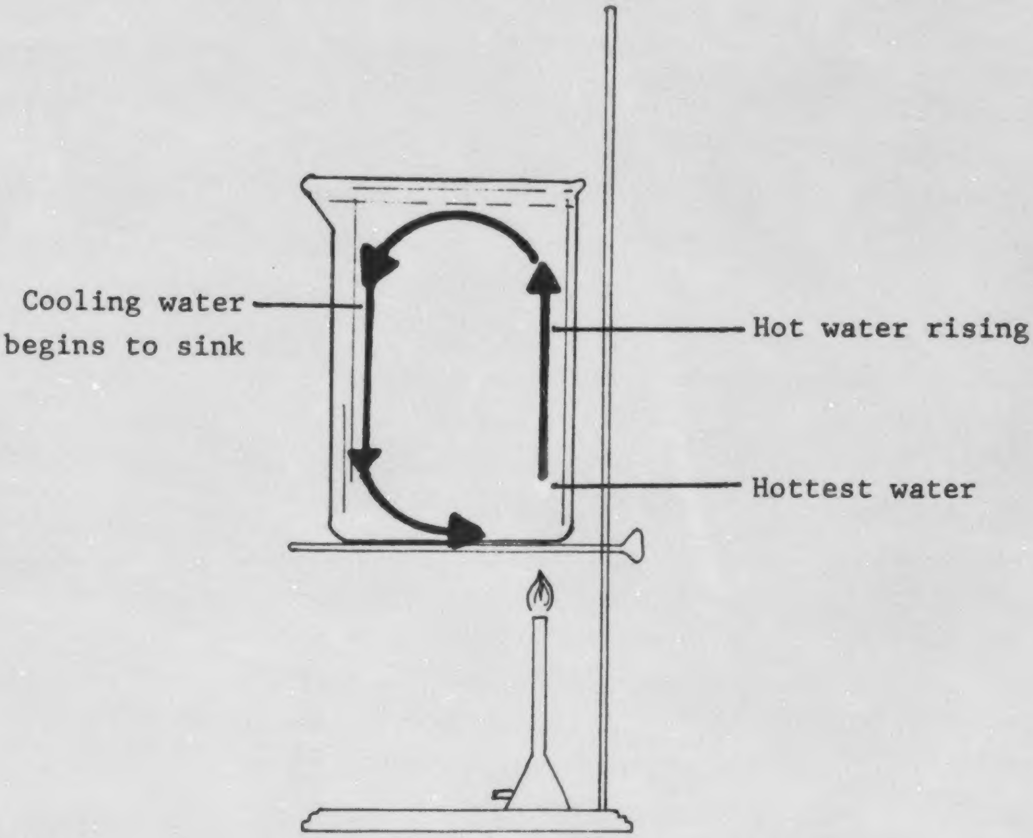
Much of the orginal debate concerning the theory of continental drift centered on the motive force. What could provide the force necessary to move these giant continents? Original proponents postulated that tidal forces were moving the continents apart. Calculations quickly showed that this was not possible. Unfortunately, scientists confused disproving the mechanism of drift with disproving the theory of drift. As it would turn out a half century later, the theory had merit even if the hypothesized force was incorrect. Present thought has large, slow moving convection currents in the earth's mantle supplying at least some of the force necessary to move the plates. In "The Force" your students will have an opportunity to construct a model of a convection cell and watch the movement of "crustal material".

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished in small groups. It is possible to do this activity as a demonstration. While the demonstration method is less preferred than the "hands on" approach, it is more preferred than omitting the activity. Before embarking on "The Force" caution your students about the proper use of Bunsen burners and/or alcohol lamps. Review fire safety and evacuation procedures. Familiarize your students and yourself with the location of fire extinguishers. Remind your students that "the drop and roll" technique is the best way to put out burning clothing. For best viewing of convection currents the water should be heated slowly. The flame should be placed near one edge of the bottom of the beaker rather than centered. If you have trouble locating fine dirt, you can dry your not-so-fine dirt in an oven and then have your students pulverize it with a mortar and pestle. Provide pot holders and remind your students that cold glass and hot glass look the same. As the activity is being conducted, circulate through the lab. Be especially attuned to unstable set-ups. Care will pay off in a successful experience. After clean up or during the next class meeting provide time for a discussion of the procedure and the results.

KEY

1. Convection currents in the beaker are caused by warm water (less dense) rising and cool water (more dense) sinking. As the water directly above the flame is heated, it rises to the surface. At the surface, it flows laterally gradually giving its heat to the adjacent water and air. As it gives up its heat, it becomes cooler and more dense. It eventually sinks and travels across the bottom to be reheated and begin another cycle.

2.



3. a. While the answer depends upon the experimental results, the sawdust generally begins to pile up at the beaker's edge. This piling up is reminiscent of the mountain building we see in certain parts of the globe.

b. Trenches occur where crustal plates collide.

4. The addition of sawdust where the convection current upwells would make our model more realistic. The sawdust would represent the ocean floor building that occurs along the mid-ocean ridges. This question provides an opportunity for the discussion of models in science and their role in helping us to understand complex systems. Have your students suggest other ways in which the model could be made more realistic.

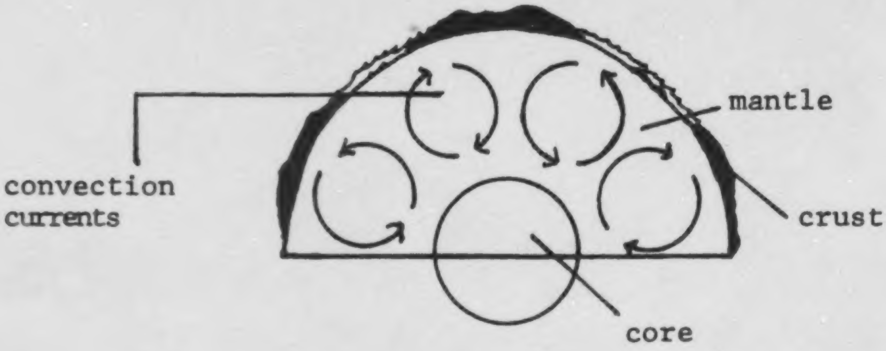
KEY WORDS

cell-like pattern
convection
currents
force
laterally
mantle
mid-ocean ridges
model
plate tectonics
rifted
theory
trench
upwelling

THE FORCE

Evidence was mounting to support the "theory of plate tectonics". (From the Greek word "tekton" meaning builder). The theory now involved sea floor spreading, continental movement and mountain building. What was the force behind these moving events?

The growth of the mid-oceanic ridges and the spreading of the sea floor result from movements below the earth's crust. Convection currents in circular patterns are thought to occur in the mantle. The currents form as mantle material next to the core is heated and rises. The heated material moves laterally ("sideways") beneath the crust. This lateral movement drags the thin oceanic crustal layers. These layers are split, or rifted, in the mid-oceans and spread laterally toward the ocean sides as the cooling current moves back toward the core. The layers pile up and are rammed under the edges of the continents.



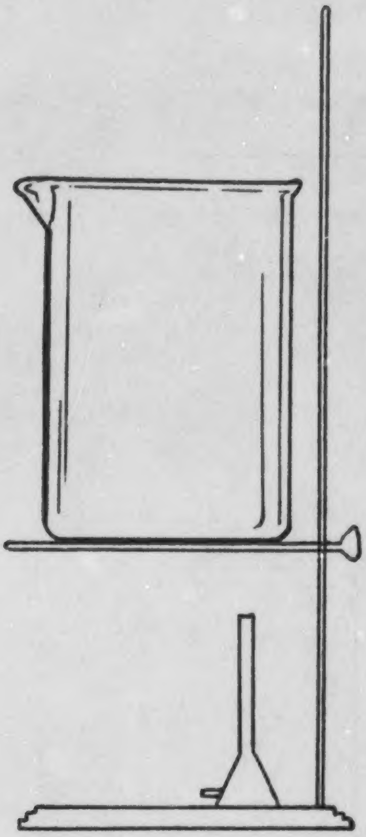
In the following activity you will have a chance to see how convection may be responsible for the movement of the earth's crust.

Materials:

500 ml Griffin beaker
ring stand and ring
tap water
Bunsen burner or alcohol lamp
food coloring
dripper
fine dirt
sawdust or fine wood chips

Procedure:

1. Add tap water to the 500 ml beaker until it is about three quarters full. Place the beaker on a ring stand.
2. Heat the water slowly by placing the Bunsen burner flame on one side of the bottom of the beaker. Place the flame on the center of the bottom.
3. As boiling just begins, add one or two drops of food coloring to the water above the flame. The pattern you see is caused by convection. In the beaker below sketch the pattern as you see it.



4. Turn off the Bunsen burner.
5. Add a handful of fine dirt to the beaker. Mix thoroughly.
6. Carefully spread a thin layer of sawdust or fine wood chips over the top of the water.
7. Relight the Bunsen burner. Heat the beaker very slowly (again, one side) and observe the flow of the fine dirt in a convection pattern.
    a. What happens to the sawdust as boiling takes place?

Analysis and Interpretation:

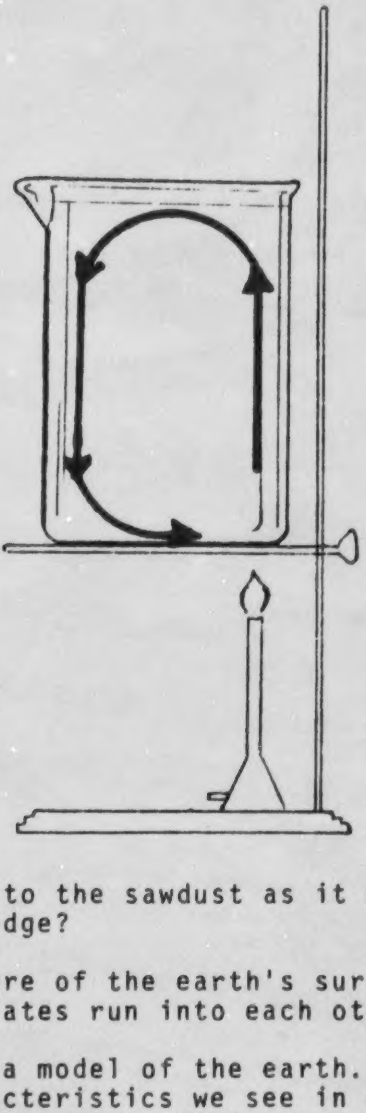
1. What caused the convection currents observed in your beaker?

2. On the drawing below label the following:

   a. the hottest water

   b. the place where cooling water begins to sink

   c. the place where hot water is rising



3. What happened to the sawdust as it moved sideways and ran into the edge?

   b. What feature of the earth's surface occurs where crustal plates run into each other?

4. The beaker is a model of the earth. It shows some of the same characteristics we see in the earth. To make it a better model what should we be adding to the surface where the convection current upwells?

TEACHER BACKGROUND - Packages

"Packages" provides your students with an opportunity to construct a simple three dimensional model of the earth's surface. Students often have difficulty in visualizing in three-demensions when given two dimensional figures. Model building offers additional opportunities for learning. In addition to the cut and paste model included in "Packages", you may wish to have your students use a variety of textures (e.g. sand, oatmeal, sawdust, barley, grits, etc.) to build a cross section of the earth in a pint or quart jar. The model can be simple or complex. Complex models would show ridges, plate collision, trenches, etc. These models can serve to reinforce the concepts of continental drift and plate tectonics which were taught previously.

Duplicate the activity pages. One set is recommended per student. The model making is simple but does provide a good exercise in direction following. Ideally, each student should make her own model. Quick drying glue (e.g. glue, stick, or rubber cement) or tape should be used to hold the model together. You may wish to have a completed model available for demonstration. Upon completion, provide time for a discussion of the "Analysis and Interpretation" questions.

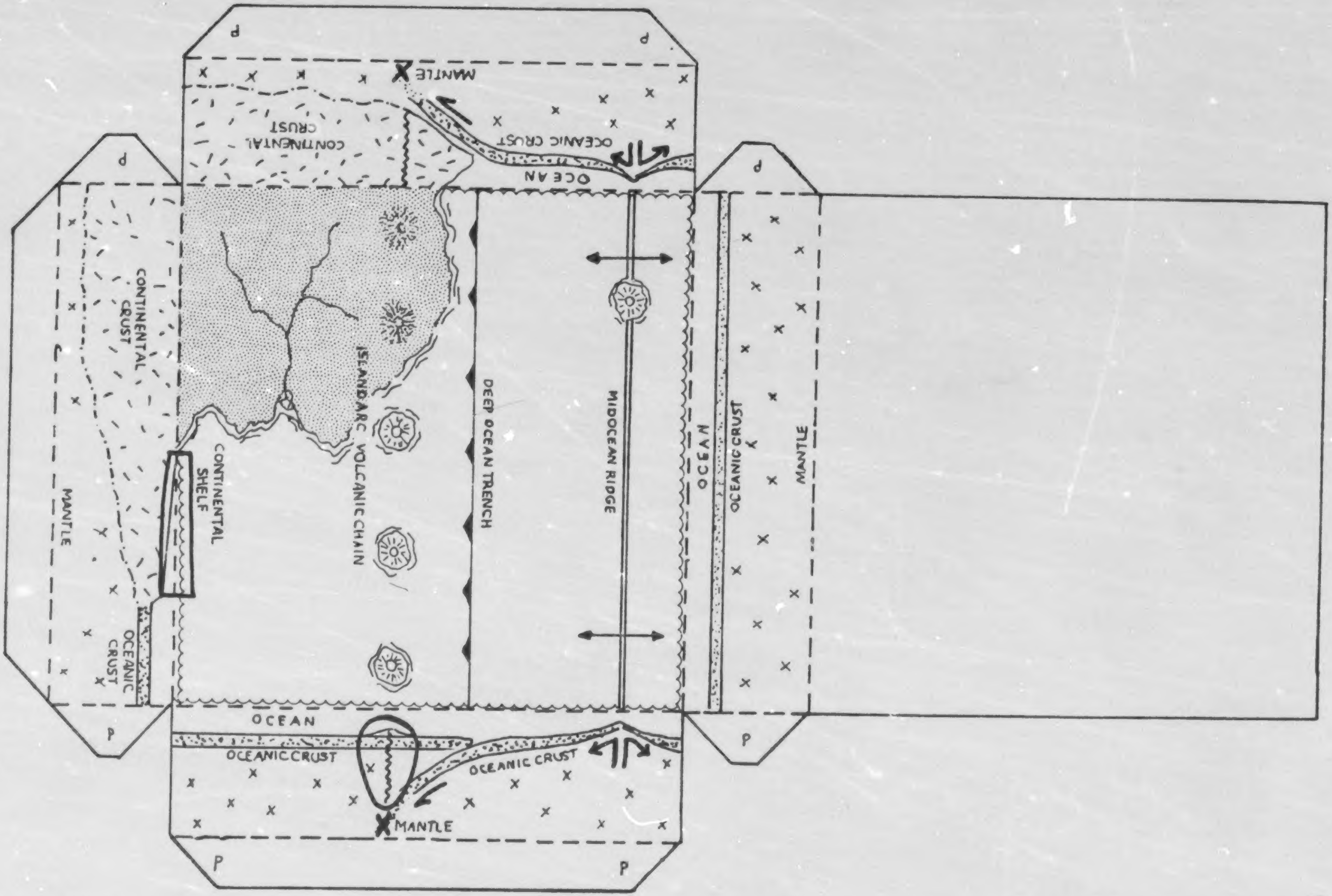
KEY

1. a. The continental crust is thicker than the oceanic crust.
   b. The continental crust floats higher above the mantle. This question is likely to cause some confusion. While the bottom of the continental crust is lower than the bottom of the oceanic crust, the top of the continental crust is also higher than the top of the oceanic crust. You can make the analogy with an ice cube floating in a glass of water.
   c. Continental crust must, therefore, be lighter than oceanic crust.
2. A completely labeled "earth package sheet" is found below.
3. a. A completely labeled "earth package sheet" is found below.
   b. New crust is formed at the mid-ocean ridges of the deep-ocean basin.

4. a. A completely labeled "earth package sheet" is found below.
   b. The Hawaiian island group is the classic example of a volcanic island arc. Other volcanic island arcs include: the Azores, the Phillipines, the Marshall Islands, the Tuamoto islands, and the Fiji islands.
5. Deep ocean trenches are thought to occur where one plate meets and dives under another.
6. A completely labeled "earth package sheet" is found below.
7. The theory of plate tectonics and continental drift hypothesizes that the continents are in relative motion and that the positions of the continents we see today are not the positions (or the continents) of the past. The positions of the continents are changing.

KEY WORDS

continental drift
continental shelf
continental crust
convection currents
crust
deep-ocean trench
mantle
mid-ocean ridge
molten
oceanic crust
plates
plate tectonics
three dimensional
two dimensional
volcanic island arc
volcano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MANTLE
CONTINENTAL CRUST
OCEANIC CRUST
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CONTINENTAL CRUST
MANTLE
OCEANIC CRUST
CONTINENTAL SHELF
ISLAND ARC VOLCANIC CHAIN
DEEP OCEAN TRENCH
MIDOCEAN RIDGE
OCEAN
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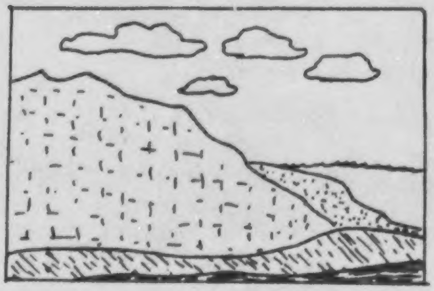


PACKAGES

It seems that the more we know about the earth, the more questions we have. It is difficult to visualize a three dimensional earth on two dimensional paper. The following activity will give you an opportunity to make a model of part of the earth's surface. Recall that scientists now think that the earth's surface is composed of large plates of crustal material. These plates are moving apart from each other at the mid-ocean ridges. Trenches form where one plate meets and dives under another. The leading edge of the diving plate is heated as it descends. The edge eventually melts and the plate once again becomes mantle material. The model you will make shows some of what we now know about these and other features and events.

Materials:

earth package sheet
pencil
scissors
tape or glue

Procedure:

1. Obtain an "earth package sheet" and scissors.
2. Cut along the outside solid lines.
3. Fold on the dashed lines.

4. Paste or tape the model together where the small "p"'s appear on the flaps.
5. Use your model to answer the following questions.

Analysis and Interpretation:

1. a. Which crust, the oceanic or the continental is thicker?

   b. Which type of crust (oceanic or continental) floats higher above the mantle?

   c. Which type of crust must therefore be lighter?

2. Use arrows to draw in convection currents beneath the surface of the mid-ocean ridge.

3. a. Place an X at the point(s) where the oceanic crust is remelted to form mantle.

   b. If the amount of crust remains the same, new crust must be formed to replace the crust that is remelted. Where is the new crust formed?

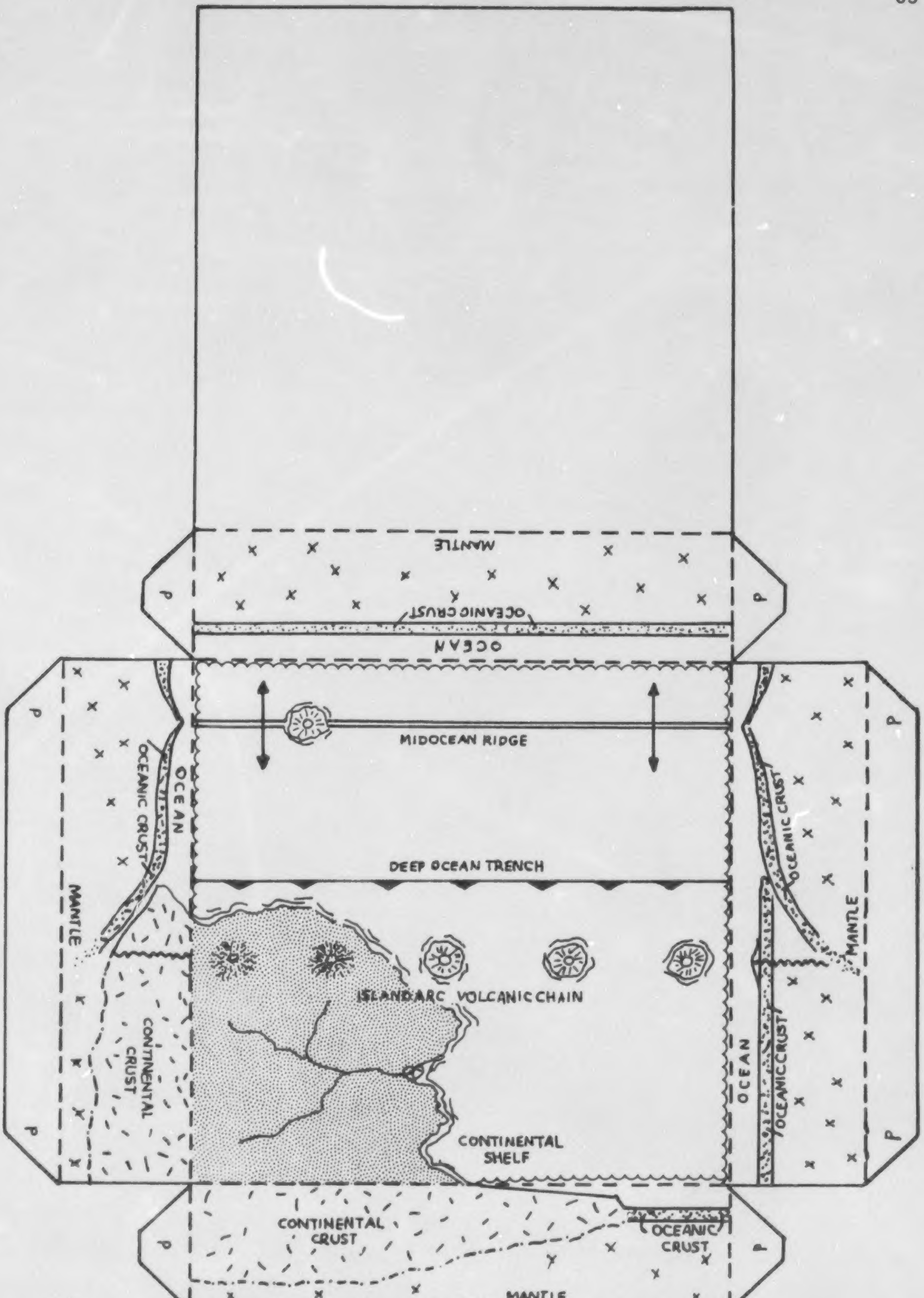
4. a. Circle the path of molten rock from the mantle to the top of an oceanic volcano.

   b. The Pacific Ocean has many volcanic islands. There are also volcanic islands in the Atlantic ocean. What island group is an example of a volcanic island arc?

5. What is thought to cause deep ocean trenches?

6. Draw a box around the profile (side view) of the continental shelf.

7. What does the theory of plate tectonics and continental drift say about the positions of the continents?


MANTLE
OCEANIC CRUST
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ISLAND ARC VOLCANIC CHAIN
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THE OCEAN FLOOR: TOPOGRAPHY

TEACHER BACKGROUND - Deep Sounds

"Deep Sounds" serves as an introduction to and preview for several activities dealing with the topography of the ocean floors. While man has been traversing the surface of the ocean for thousands of years, it has only been within the last half century that we have been able to say with any reasonable certainty how the bottom of the ocean looks. Submarines and submarine warfare fostered the development of echo-sounding and sonar equipment. These devices have permitted us to make continuous recordings of depth and thereby map the bottom with considerable ease and accuracy. The information obtained provides important evidence in support of the theory of plate tectonics. It now appears that sea floor topography is, in fact, largely a result of the processes involved in plate movement. Bottom profiles have also provided information important to sea bed miners and oil drillers. "Deep Sounds" looks at some of the discoveries.

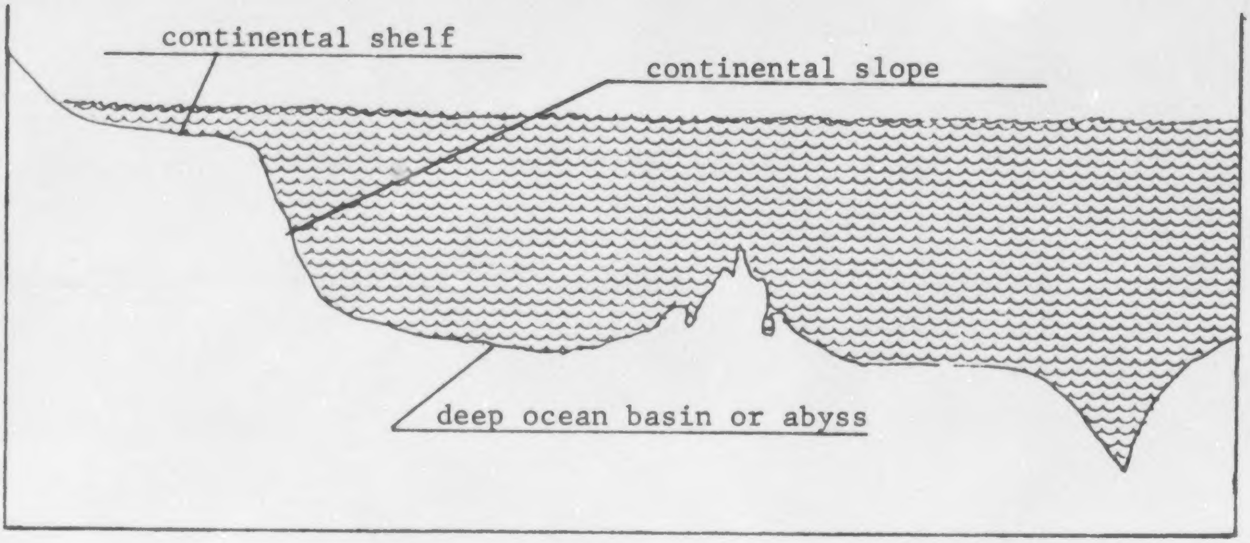
Duplicate the text pages. One set is recommended per student. This activity is best accomplished by individual students as homework or as an in-class assignment. There is merit in having the students meet in small groups after each individual has completed the assignment. The groups provide an opportunity to exchange and compare answers prior to a general class discussion of the material. This topic lends itself well to bulletin board displays. Supplement the text material with films and/or filmstrips. Encourage your students to bring in articles and other supplementary materials relating to the topics under consideration.

KEY

1. Fishers are interested in the bottom profile to keep from running aground and to keep from entangling and losing their gear. Since certain fish and/or shellfish are found at specific depths or over specific types of bottoms, fishers also use bottom profile information to tell them where to fish. The

bottom profile reporduced in the text shows another reason fishers are interested in echo sounders. Schools of fish show up as shaded blips on the recorder. The ability to pin-point schools of fish has increased the fisher's ability to locate and catch fish. New echo sounders can even detect individual fish. There is some reason for concern that this sophisticated gear may lead to overfishing and the extermination of some (or many) fish stocks.

2.

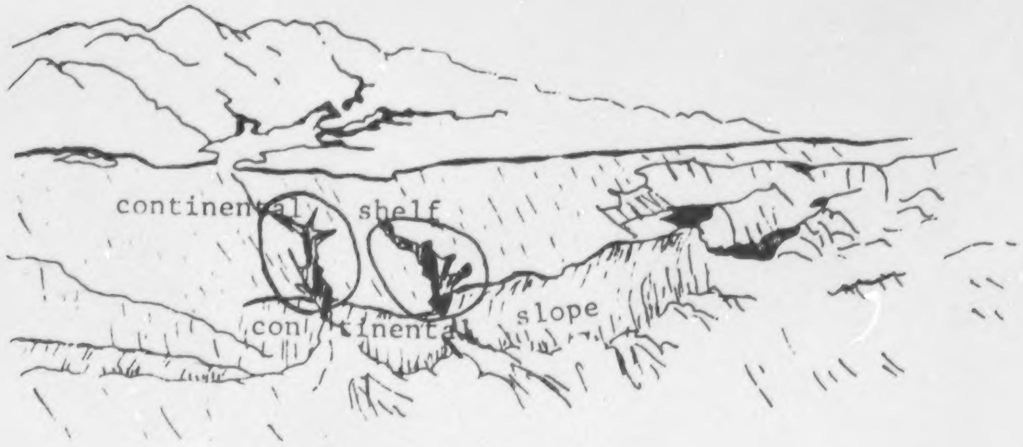

continental shelf
continental slope
deep ocean basin or abyss

3.

4. a. Turbidity currents are torrents of silt-laden water that flow down the continental slopes. Essentially they are underwater avalanches that flow because the currents are more dense than the surrounding sea water.

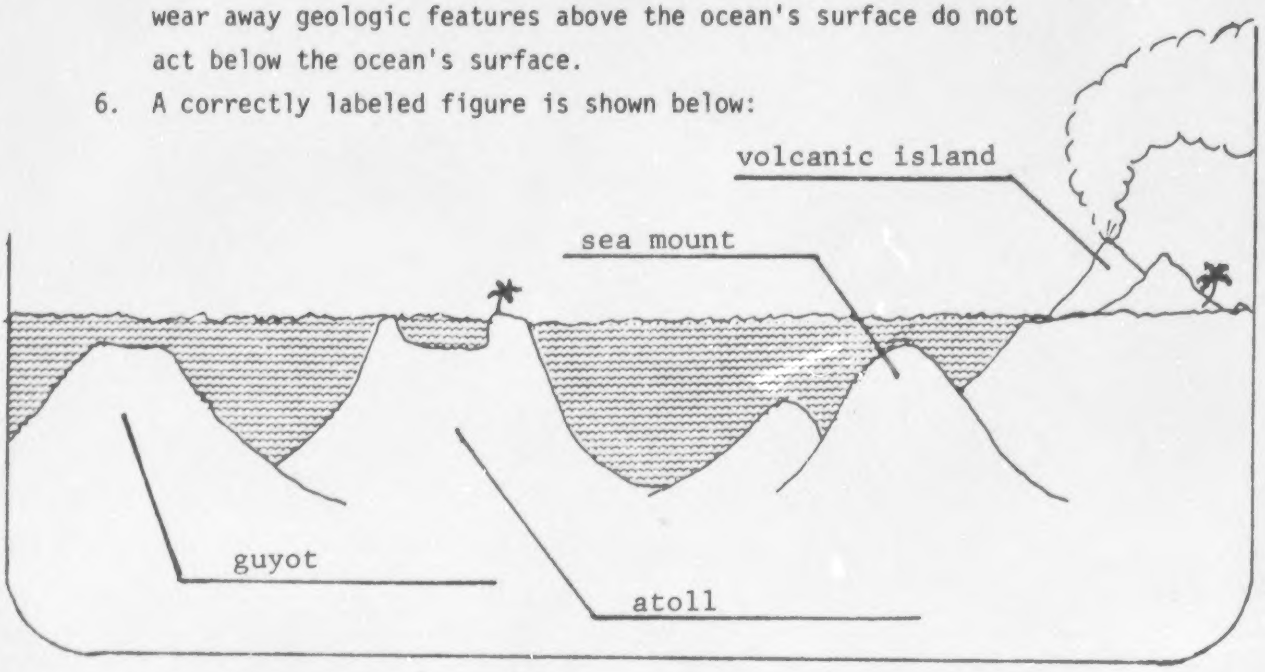
   b. Turbidity currents shape the continental slope by scouring deep submarine canyons as they flow downward.

   c. The most likely locations for turbidity currents are shown on the figure below:


continental shelf
continental slope

5. Submarine peaks, ridges and other features are preserved relatively unchanged because the forces of wind, rain and frost that wear away geologic features above the ocean's surface do not act below the ocean's surface.

6. A correctly labeled figure is shown below:


volcanic island
sea mount
guyot
atoll

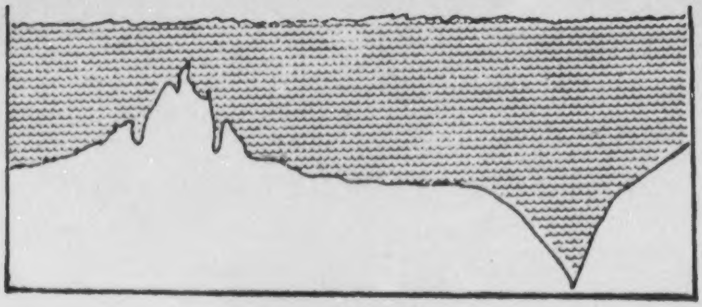
7. The echo-sounder and sonar are major research tools that have enabled oceanographers to "see" the ocean floor.

KEY - Name that Shape

"Name that Shape" serves as a vocabulary review for "Deep Sounds". The correct answers are found on the next page.

KEY WORDS

abyss
abyssal plain
atoll
avalanche
colliding
continental shelf
continental slope
coral
crust
debris
deep-ocean basin
dense
guyots
orient
plates
ridges
seamounts
silt
sonar
soundings
submarine canyons
trench
turbidity currents
volcano



NAME THAT SHAPE

I. Scientists have measured the great depths and found that the shape of the ocean floor, or TOPOGRAPHY, is very much like that on land. Some of these underwater formations are listed below. Draw a line from each word to the correct definition.

1. abyssal plain
2. atoll
3. continental shelf
4. guyot or plateau
5. ridge
6. seamount
7. trench
8. volcanic island

A. a volcanic peak rising from the sea floor that is "flat-topped" because of earlier wave action.

B. the sea-bed along continents that forms a gentle slope. It is covered by shallow water ranging from a few to hundreds of kilometers wide.

C. a submarine volcanic peak.

D. a seamount with a ring of coral growing around it.

E. narrow, deep cuts with steep slopes.

F. a peak formed by lava rising above sea level.

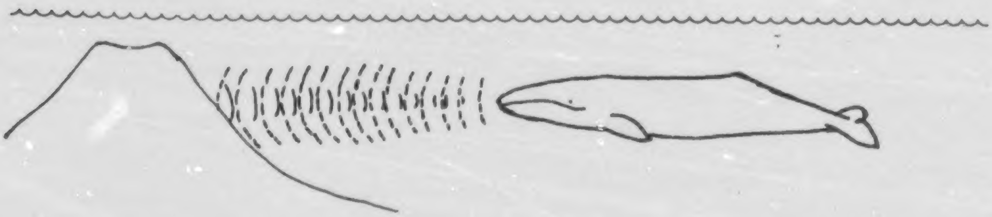
G. a long, narrow rise in the sea floor with steep sides.

H. deep; covered with a thin layer of SEDIMENTS.

DEEP SOUNDS

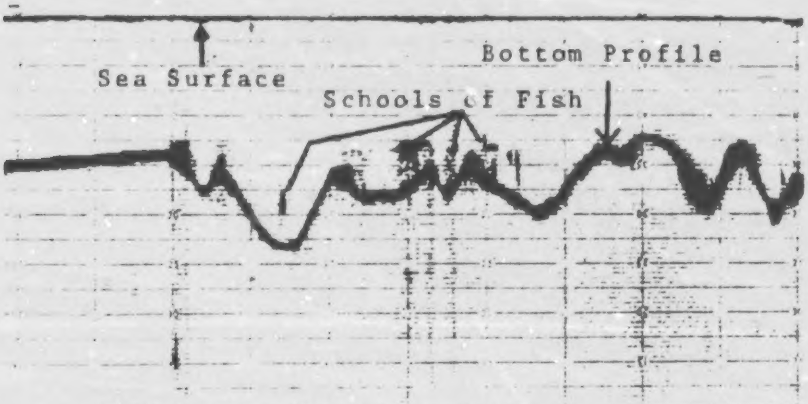
Nearly three quarters of the earth's surface is under water. What shapes have the moving plates of the earth's crust fashioned beneath the ocean's surface? Gray whales and other marine mammals dive into the darkened depths of the seas. These animals depend upon a knowledge of the bottom shapes to keep from colliding with the ocean floor.

How do the whales sense the bottom? Scientists believe that whales orient themselves in space through some sort of sonar. The whale sends out a sound impulse. The impulse is reflected by the bottom and returns to the whale. The longer the time before the sound returns, the deeper the bottom. Using this sonar the whales can travel in the darkness without danger.



Until the 1920's man did not have anything like sonar. To chart the shape of the bottom we had to make soundings by dropping a marked, weighted line overboard. A measurement of the depth of the water is called a sounding. By the 1950's sonar was available and being used by oceanographers to map the shape of the sea bottom. The ocean bottom began to give up its secrets. The bottom was more rugged than anyone had imagined.

1. Oceanographers are not the only people interested in the shape of the ocean floor. Why might a fisher be interested in the bottom profile?

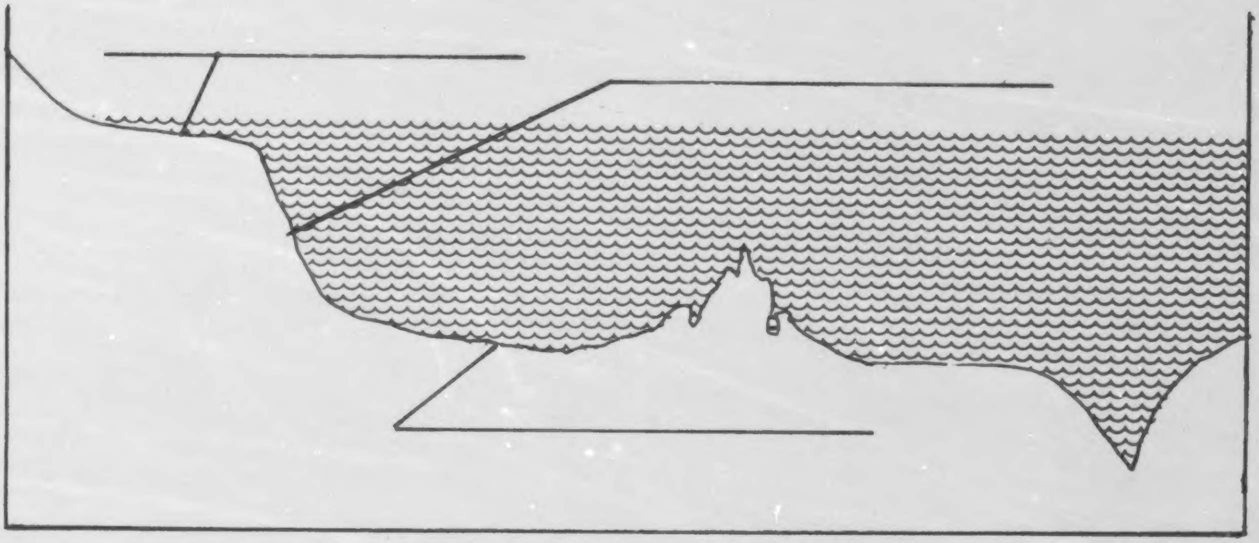


BOTTOM PROFILE
REPRODUCED FROM A FATHOMETER TAPE

Beneath the flat surface of the sea lay mountains taller than Everest. Oceanographers discovered trenches deep enough to swallow half a dozen Grand Canyons. They also found steep cliffs long enough to stretch from New York to San Francisco.

The data has revealed that the floor of the ocean is divided into three great domains or regions. The first domain is the continental shelf. The shelves are the shallowly submerged edges of the continents. Marine life is abundant on the continental shelves. At the continental slope, the second domain, the sea floor plunges two miles to end at the deep-ocean basin. The deep-ocean basin or abyss forms the third great domain of the oceans.

2. On the drawing below label the a) continental shelf b) continental slope, and c) the deep ocean basin or abyss.

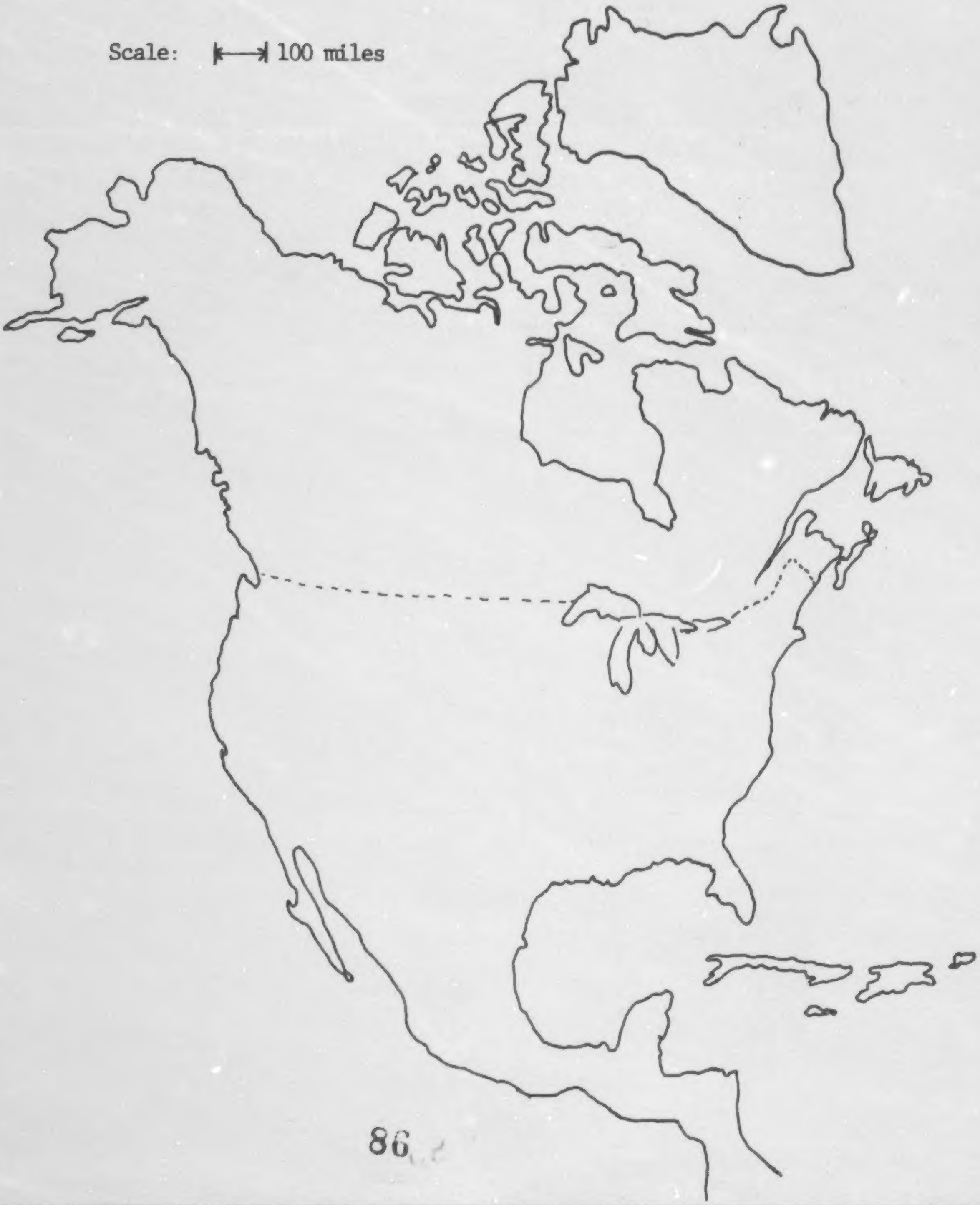


Continental Shelf:

The continental shelves are found on most of the earth's coasts. The continental shelves slope gently away from the shore to a depth of about 200 meters (650 feet). Rivers built them. As time passed, rivers washed great loads of gravel, sand and silt onto the shoulders of the continental blocks. Off many coasts, especially on the Atlantic, the shelf is wide, projecting more than 100 miles into the sea. The widest shelf anywhere stretches 800 miles into the sea off the Arctic shore of Siberia. There is almost no shelf off southeastern Florida. Off Florida the Gulf Stream runs like a swift underwater river. It sweeps the offshore sea bottom clean of shelf-building debris. Off mountainous shores like the Pacific coast of the American continents, there are few rivers to pile up much sediment. Consequently, the continental shelf is apt to be narrow or nonexistent.

3. Use the information above to draw the continental shelves on the map of North America.

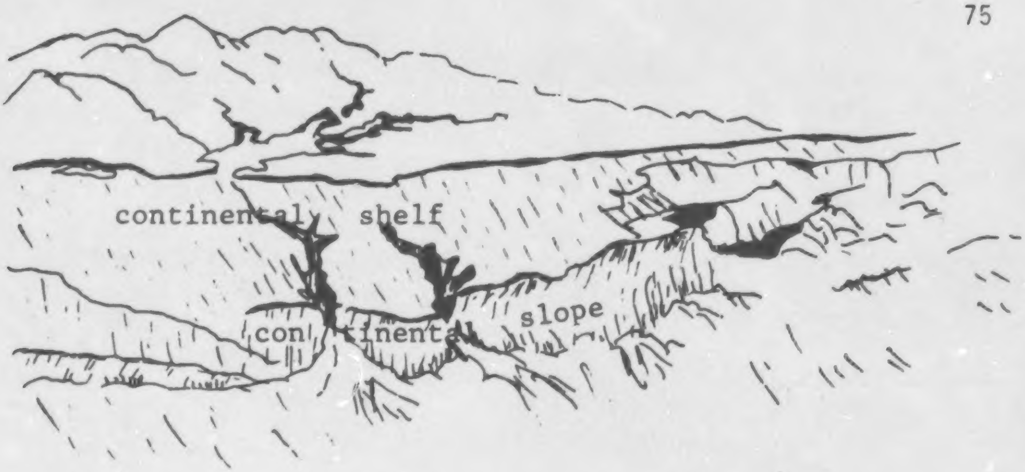
Scale: |⟷| 100 miles



Continental Slope:

At the outer edge of the continental shelves, the land plunges down. The slope sometimes falls unbroken for two to three miles. These continental slopes are among the most imposing features of the entire earth. They are the highest and longest walls in the world.

Nearly everywhere that oceanographers have probed the continental slope so far, they have found deep gorges and canyons cut into its face. The force that had carved them was a mystery. Many were too far off shore, and in water too deep, to be explained as drowned river beds. Earthquakes had clearly opened a few but not all of these gorges. Scientists now believe they were cut into the continental slopes by powerful underwater avalanches called turbidity currents. These are turrent of silt-laden water that flow down the slopes. The water flows downward because it is (heavier) than surrounding sea water. An earthquake or load of sediment on the continental shelf can send silt rushing down the slope. The silt, flowing at express-train speed, gouges out a canyon as it goes. Turbidity currents can roll on for hundreds of miles. As they slow down, they spread out thick new layers of sediment. These layers of sediment form the abyssal plain.



4. a. What is a turbidity current?

   b. How do turbidity curents shape the continental slope?

   c. On the picture of the continental slope found above,circle a place where turbidity currents are likely to have occurred?

The Deep-Ocean Basin or Floor:

The deep-ocean floor begins at the foot (bottom) of the continental slope. It is the biggest of the ocean's three geographic domains, comprising over 70% of the total sea area. In this domain of darkness, man has made his most startling discoveries about the earth's hidden surfaces.

Amazingly enough, the peaks, cones, ridges and cliffs formed beneath the sea have been preserved largely unchanged. Beneath the sea there is no wind, rain and frost to wear away these features. On the Pacific floor, for example, there is a cliff half a mile to a mile high and 3,000 miles long.

It is as sharp and jagged as if it had been wretched from the sea bottom just yesterday. In spite of its appearances, in some places it is 70 million years old.

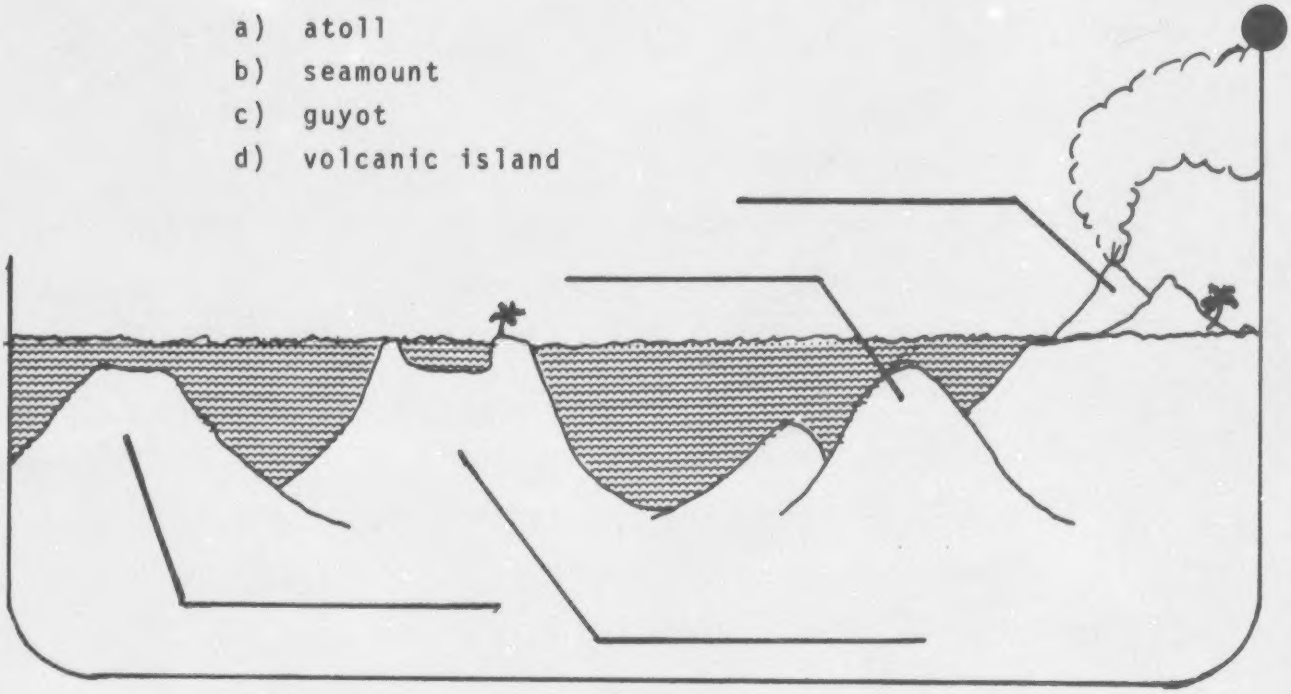
The flat sections of the deep-ocean floor turned out to be flatter than anything ever seen on land. Called abyssal plains these level expanses lie smooth and even as a dance floor. Core samples from these abyssal plains show that they were formed by sediments from turbidity currents. After carving canyons in the continental slope, the turbidity currents spread out when they reached the sea floor. Sediments carried by the currents gently filled every sea-bed crevice with sand and mud washed down from the coasts.

5. How are the submarine ridges and other features preserved unchanged?

Several other interesting features are found on the ocean floor. Seamounts are cone-shaped submarine volcanos which rise from the floor. In some areas, the lava flow has caused the seamount to rise above the surface of the ocean. These seamounts then form volcanic islands. The Hawaiian islands are examples of volcanos rising from the ocean floor. Some of the seamounts have had their tops worn away by earlier wave action. These "flat-topped" volcanic peaks are called guyots (pronounced "gee oh"). Some seamounts close to the surface support the growth of coral animals. The coral can form a ring around the island or it can form a ring on top of a guyot. These ringed coral islands are called atolls.

6. On the diagram below label the following features:

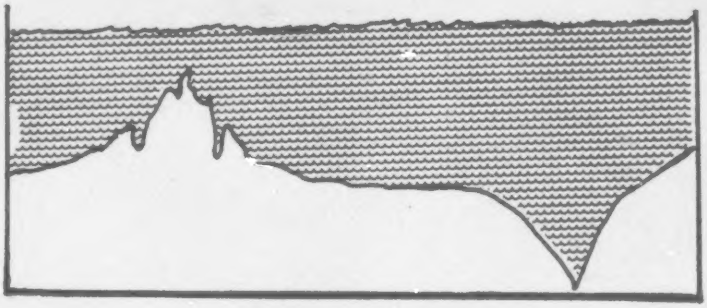
   a) atoll
   b) seamount
   c) guyot
   d) volcanic island



The ridges and trenches we associate with plate tectonic are also found in the deep ocean basin. The rises are thought to be areas in which the seafloor is spreading and growing. The deep trenches occur where one plate dives under another. These steep-sided canyons are deep enough to swallow many Grand Canyons.

We once thought the floor of the ocean was entirely smooth. The sediment covered abyssal plains are, indeed, very smooth. We have found, however, that other parts of the floor are anything but smooth. New research tools have let us explore the ocean bottom more fully than ever before. As new research tools are developed, other secrets are sure to be revealed.

7. What was the major research tool that enabled oceanographers to "see" the ocean floor?



NAME THAT SHAPE

I. Scientists have measured the great depths and found that the shape of the ocean floor, or TOPOGRAPHY, is very much like that on land. Some of these underwater formations are listed below. Draw a line from each word to the correct definition.

1. abyssal plain
2. atoll
3. continental shelf
4. guyot or plateau
5. ridge
6. seamount
7. trench
8. volcanic island

A. a volcanic peak rising from the sea floor that is "flat-topped" because of earlier wave action.

B. the sea-bed along continents that forms a gentle slope. It is covered by shallow water ranging from a few to hundreds of kilometers wide.

C. a submarine volcanic peak.

D. a seamount with a ring of coral growing around it.

E. narrow, deep cuts with steep slopes.

F. a peak formed by lava rising above sea level.

G. a long, narrow rise in the sea floor with steep sides.

H. deep; covered with a thin layer of SEDIMENTS.

TEACHER BACKGROUND - "Sounds Good To Me"

"Sounds Good To Me" provides your students with an opportunity to transform echo sounding data into a bottom profile. Echo sounders, sonar, and similar devices have given oceanographers a window on the underwater bottom. The theory behind these devices is quite simple. If we know the speed of sound in water, we can determine the depth by measuring the time it takes for a sound wave to go from a ship to the bottom and back to the ship. While the theory is simple, the practice has become quite sophisticated. Not only can oceanographers obtain detailed pictures of the bottom profile, they can determine something about the composition of the bottom, stratification and thickness of bottom sediments, and they can detect schools of fish and even individual fish between the surface and the bottom. Although all of the calculations your students will be performing are now done within the echo sounder before the information is displayed, it is illustrative to have your students work through these calculations to help them understand the concept involved in echo sounding.

Duplicate the activity pages. One set is recommended per student. If possible, supplement this activity with posters, films and other visual aids which show bottom topography and the use of echo-sounding equipment. This activity may be accomplished by individual students working independently or by pairs. It may be wise to demonstrate the mechanics required to set-up the problems before your class begins to work independently. It is possible to assign the activity as homework although most classes benefit from having the instructor present as the students work through the data. Allow time for a group discussion of the results upon completion of the activity.

KEY - text questions

1. Since the total time represents the time required for the sound wave to travel from the ship to the bottom and back from the bottom to the ship, the time must be divided by two to find the one-way travel time.

2. $$\text{Depth} = \frac{\text{time down and back}}{2} \times 1460 \text{ m/sec (speed of sound in water)}$$

$$\text{Depth} = \frac{10 \text{ seconds}}{2} \times 1460 \text{ m/sec}$$

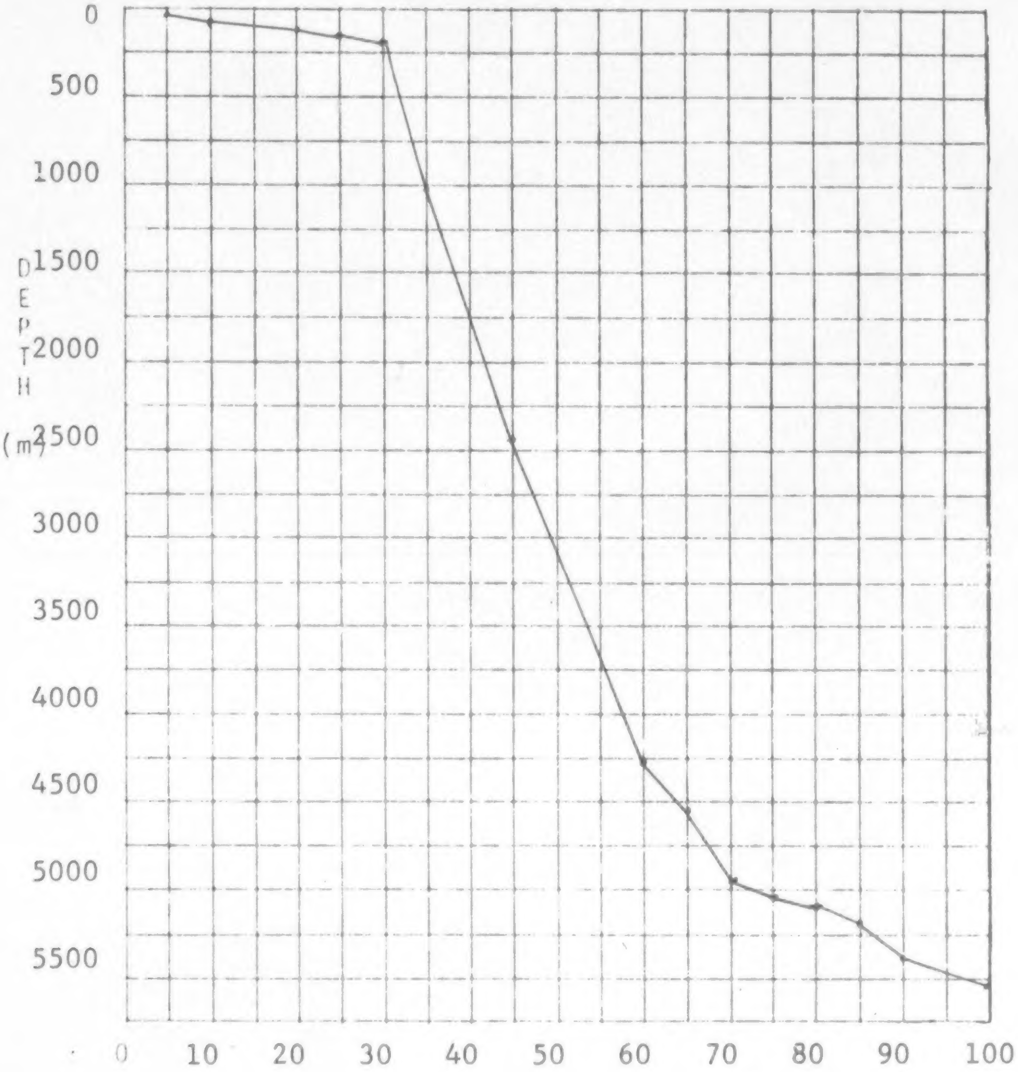
$$\text{Depth} = 7300 \text{ meters}$$

Prodedure Questions

1. A completed data chart is included below.

Station	Distance from Shore km	Travel Time sec	Depth of Ocean m
1	5	0.07	51.20
2	10	0.14	102.20
3	20	0.28	204.40
4	25	0.35	255.5
5	30	0.42	306.6
6	35	1.40	1022.0
7	45	3.36	2452.8
8	60	5.88	4292.4
9	65	6.30	4599
10	70	6.76	4934.8
11	75	6.93	5058.9
12	80	7.00	5110
13	85	7.21	5263.3
14	90	7.42	5416.6
15	100	7.56	5518.8

OCEAN DEPTHS ALONG THE PATH OF THE R/V NORDIC MAID



DISTANCE FROM SHORE

Analysis and Interpretation Questions

1. The ocean feature seen at station 1 is the continental shelf.
2. The ocean feature seen at station 7 is the continental slope.
3. The ocean feature seen at station 14 is the deep-ocean basin or abyssal plain.
4. Fishers learn to recognize these false bottoms as schools of fish and set their gear accordingly. The use of electronic gear to sense the presence of schools of fish has increased tremendously the ability of the fisher to locate fish. It has also increased the likelihood of over-exploitation of certain fish stocks.
5. Two reasons fishers have echo sounding equipment on board their boats may include the following:
   a. to keep from running aground.
   b. to keep from fouling their nets and gear on underwater obstacles.
   c. to aid in the location of fish.
   d. to pinpoint, with the aid of charts, the vessel's location.
6. a. Small scale ocean features (i.e. those less than 5 or 15 kilometers in size) are most likely to be missed using this procedure. Virtually all of the echo sounding equipment now in use provides a continuous recording of the bottom profile. Using a continuous recording device assures that even small features will show up providing that they are beneath the moving ship. Side scanning sonar is now being developed which allows a single ship to map a swath instead of a line.
   b. Oceanographers prefer to use equipment that gives a continuous sounding because it reduces the risk of missing small (but potentially important) sea floor features.

KEY WORDS

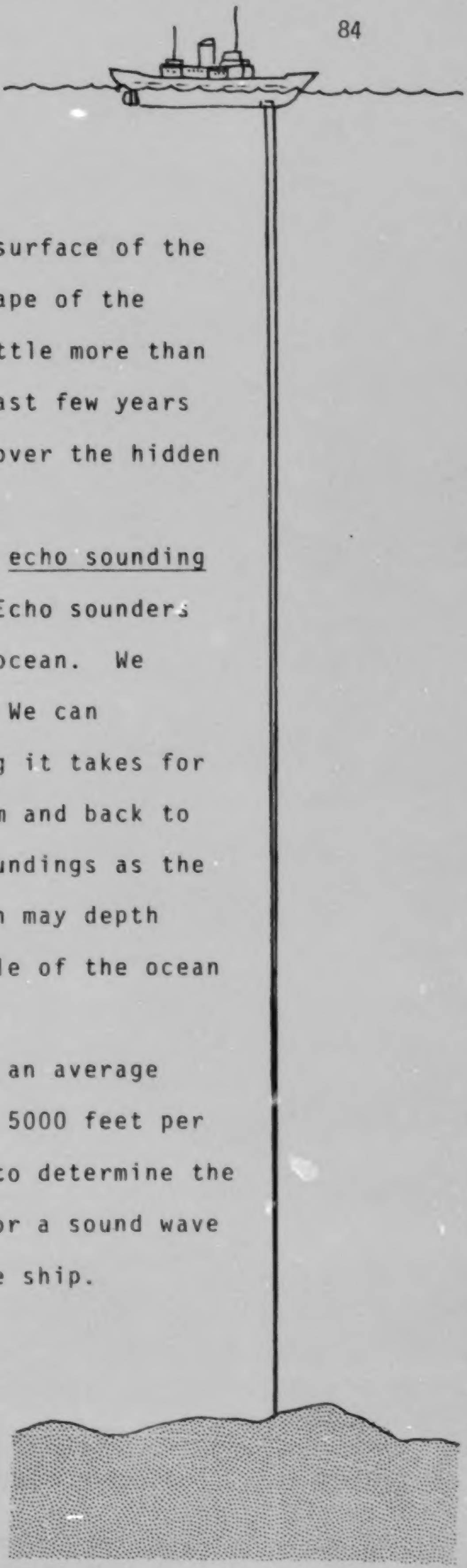
abyssal plain
average
calculate
continental shelf
continental slope
deep-ocean basin
echo sounding
grid
horizontal axis
ocean feature
phenomenon
plot
points
sonar
vertical axis

'SOUNDS GOOD TO ME'

For centuries man has sailed the surface of the oceans. Sailors wondered about the shape of the bottom of the ocean. They could do little more than wonder. It has only been within the last few years that oceanographers have begun to discover the hidden secrets of the ocean floor.

Scientists use a technique called echo sounding to determine the depth of the ocean. Echo sounders bounce sound off of the bottom of the ocean. We know how fast sound travels in water. We can determine the depth by knowing how long it takes for sound to go from the ship to the bottom and back to the the ship. By making continuous soundings as the ship moves along, oceanographers obtain may depth readings. From these readings a profile of the ocean bottom can be made.

Sound waves move through water at an average speed of 1460 meters per second (about 5000 feet per second). We can use this information to determine the depth when we know the time it takes for a sound wave to travel to the bottom and back to the ship.



Depth = $\frac{\text{time down and back}}{2} \times$ 1460 mi/sec. (speed of sound in water)

1. Why do we divide the total time by 2 before we multiply by the speed of sound in water?

2. If the recorded time down and back is 10 seconds, what is the depth of the ocean?

In the following activity you will use data collected by the Research Vessel *Nordic Maid*. You will use the data to calculate depths and to plot a profile of the ocean bottom.

Materials:

R/V *Nordic Maid* sounding data

graph paper

pencil

scratch paper

Procedure:

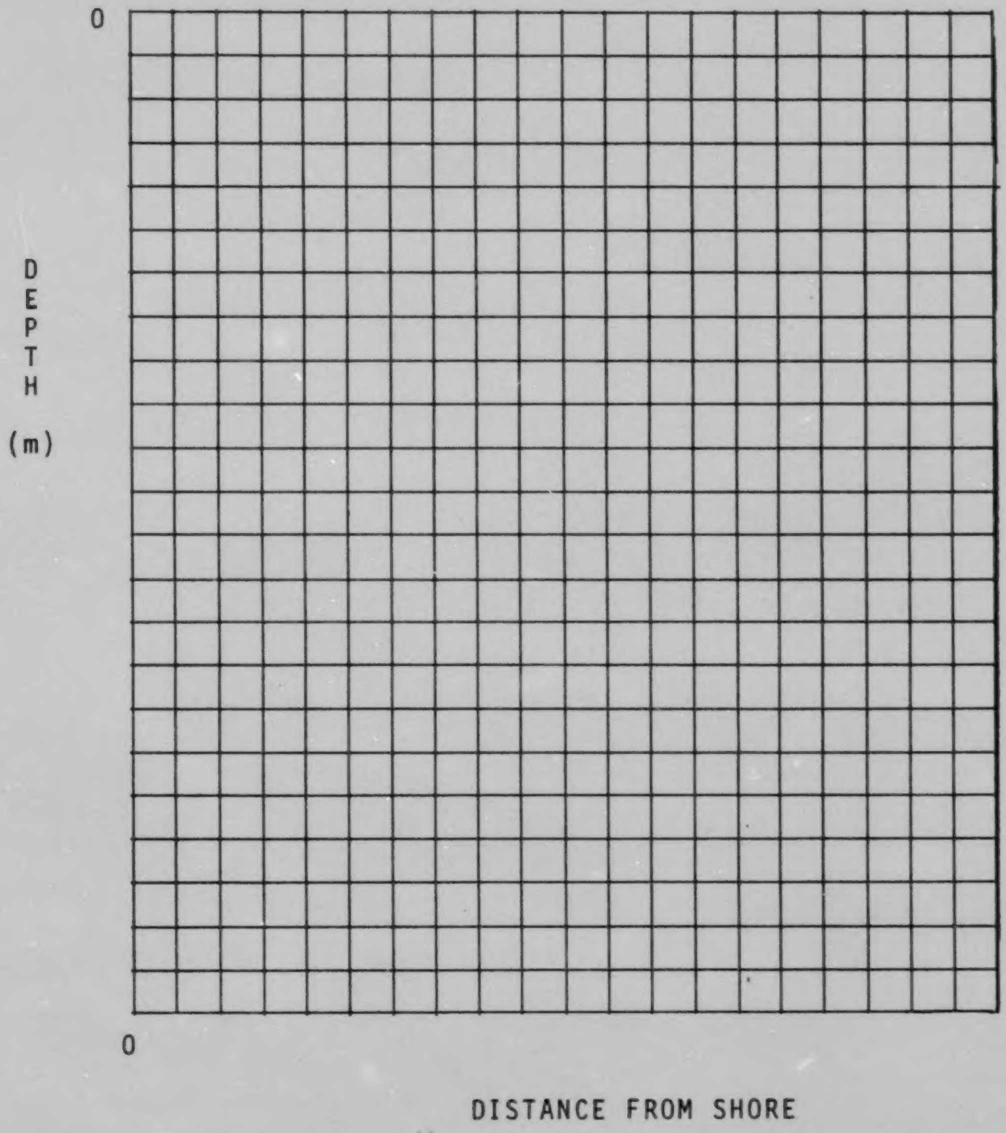
The R/V *Nordic Maid* is cruising due north mapping the ocean bottom. The time required for a sound wave to travel from the boat to the bottom and back to the boat is given for each of 15 stations sampled.

1. Use the data below to determine the depth of the ocean along the route. Make your calculations on scratch paper. Place the answers in the proper boxes.

Station	Distance from Shore km	Travel Time sec	Depth of Ocean m
1	5	0.07	
2	10	0.14	
3	20	0.28	
4	25	0.35	
5	30	0.42	
6	35	1.40	
7	45	3.36	
8	60	5.88	
9	65	6.30	
10	70	6.76	
11	75	6.93	
12	80	7.00	
13	85	7.21	
14	90	7.42	
15	100	7.56	

2. Now you have some figures for depths. Plot these figures to see what a profile of the bottom would look like. The bottom of the graph (horizontal axis) should show the distance from shore. The left hand side of the graph (vertical axis) should give the ocean depth. Plot the depth at each station.

OCEAN DEPTHS ALONG THE PATH OF THE R/V NORDIC MAID



100

3. After you have plotted the depths connect the points (dots) with a smooth pencil line. This line reflects the shape of the ocean bottom along the path of the R/V Nordic Maid.

Analysis and Interpretation:

1. What is the ocean feature seen at station 1?

   ____

2. What is the ocean feature seen at station 7?

   ____

3. What is the ocean feature seen at station 14?

   ____

4. If a school of fish is present under the R/V Nordic Maid, the echo sounder will show a "false bottom" where the school of fish is located. How might this "false bottom" phenomenon be of use to fishers?

   ____

   ____

5. What are two reasons many fishermen have echo sounding equipment on board their boats?

   a. ______________________________

   b. ______________________________

6. Soundings were made every 5 to 15 kilometers.

   a. What size ocean features might be missed using this procedure?

      ____

   b. Why do oceanographers prefer to use equipment that gives a continuous sounding?

      ____

      ____

TEACHER BACKGROUND - Retracing the Steps of Columbus

"Deep Sounds" and "Sounds Good To Me" provided your students with an introduction to bottom topography and echo sounding. "Retracing the Steps of Columbus" provides the data necessary to construct a bottom profile of the Atlantic ocean basin from Cape Cod to Gilbraltar. The profile reveals tectonic information and clearly shows the mid-Atlantic ridge, seamounts and other ocean features.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished in groups of two pairs. One pair plots the data from Cape Cod to mid-ocean while the second pair plots the data from mid-ocean to Gibraltar. It is imperative that both teams use the same horizontal and vertical scales. Demonstrate the technique and on the black board write the scales used (i.e. horizontal, one square = 100 kilometers; vertical one square = 300 meters.). Have one member of each pair read off the data while the second member plots the points. In this manner, the plotter reduces the risk of mislocating points inherent in moving eyes from graph to data to graph etc. As always, provide your students with any assistance they may require during the activity. Allot time for a discussion of the activity and the questions in the "Analysis and Interpretation" section. Plan to post the finished bottom profiles on a classroom bulletin board so that the groups may have a chance to compare their results.

KEY

1. See completed bottom profile included below. The North American side has a wider continental shelf.
2. a. See completed bottom profile.
   b. The youngest rocks would be found at the mid-Atlantic ridge, about 3075-3090 kilometers from North America.
3. a. A volcanic island is found about 1010 km east of the mid-Atlantic ridge.
   b. A seamount is found about the same distance (1010km) west of the mid-Atlantic ridge.
4. a. The difference in height from the lowest point (5100m) to the highest point (500m) is 5600m.

b. The horizontal distance between the highest and lowest points is 660km. Essentially the highest point descends without interruption to the lowest point.

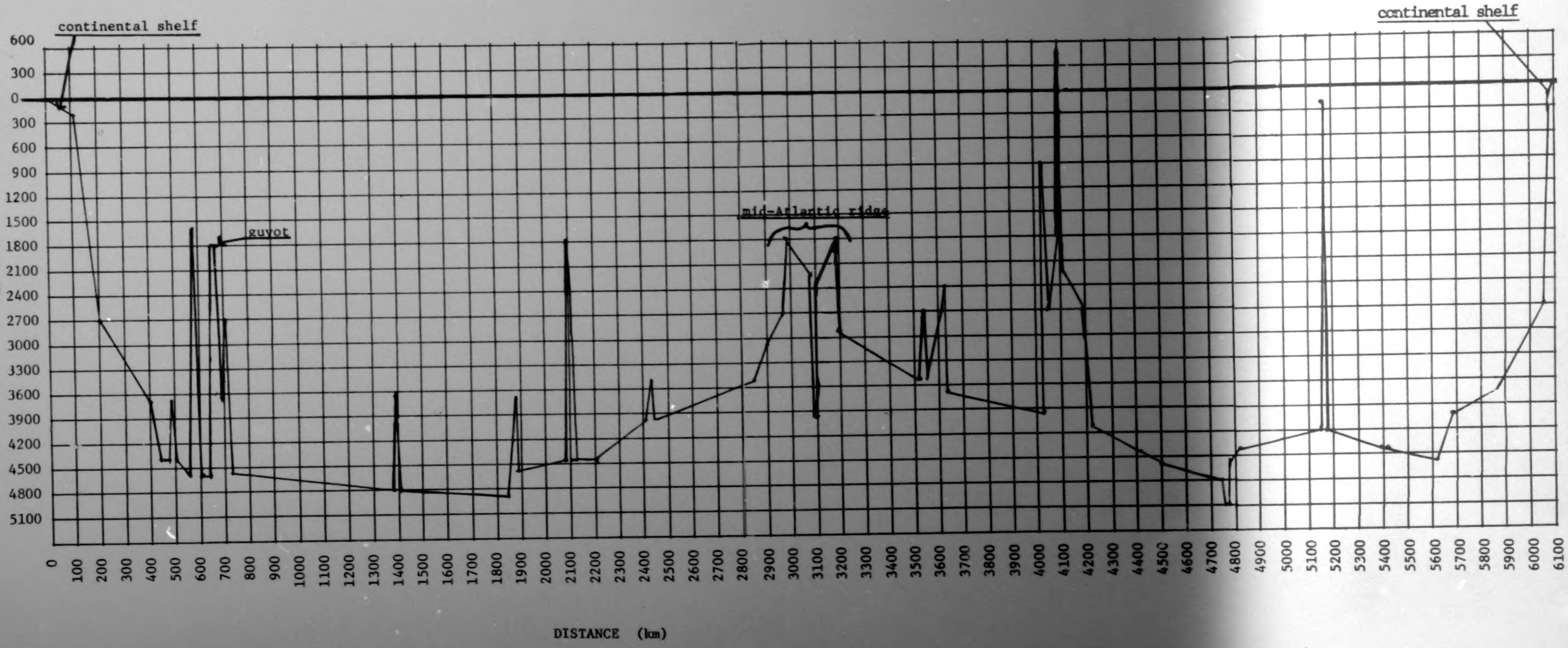
5. a. See completed bottom profile.

   b. The suspected cause of the flat top is the planing action of ocean waves which occurred when the seamount protruded above sea level.

6. The simplest way to obtain a more detailed profile of the bottom of the Atlantic Ocean would be to obtain and/or plot more data points along the traverse.

KEY WORDS

bottom profile
continental shelf
difference
echo sounding
geologic feature
guyot
horizontal
horizontal axis
kilometers
mid-Atlantic ridge
mirror image
profile
seamount
vertical
vertical axis


continental shelf
continental shelf
guyot
mid-Atlantic ridge
600
300
0
300
600
900
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200
4500
4800
5100
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5600
5700
5800
5900
6000
6100
DISTANCE (km)

RETRACING THE STEPS OF COLUMBUS

What kinds of information can we obtain from echo soundings? The locations of the continental shelves are revealed by soundings. Geologists searching for oil and minerals are interested in locating these deposits on the shelves. Other geologists studying the forces that have shaped the face of the earth also use echo soundings to provide information to test their theories.

In the following activity you will use sounding data to construct a bottom profile for the Atlantic Ocean. Using this profile you will be able to answer questions of interest to research geologists.

Materials:

- data sheet
- graph paper
- pencil
- ruler or straight edge
- tape or glue

Procedure:

1. For this activity you will be working in groups of four. Divide your group into two pairs. One pair of students from your group will chart profile A. The other pair of students will chart profile B.

2. Obtain either Profile A or Profile B data sheet. The 40 data points on your profile represent soundings from a ship as it traverses half of the Atlantic Ocean.
3. Pair A will chart Profile A while Pair B will chart Profile B. Both teams must use the same horizontal and vertical scales. For the horizonatal scale, one square will equal 100 kilometers (km). One vertical square will equal 300 meters.
4. Label the horizontal axis "Distance (km). Pair A will label the vertical axis "Depth (m)" along the left paper margin. Pair B should label the vertical axis along the right paper margin.
5. Pair A will begin labeling the horizontal axis starting at 2900 km and ending at 6100 km.
6. Plot points for your profile and connect them with a solid line. (Use your ruler or straight edge)
7. After both pairs are finished, use tape or glue to join the two halves at the section where they overlap.
8. Use your completed bottom profile to answer the questions in the "Analysis and Interpretation" section which follows.

Analysis and Interpretation:

1. Label the continental shelves. Which side of the Atlantic has a wider continental shelf?

2. a. The mid-Atlantic ridge is thought to be the location where new ocean floor is formed. The two sides of the ridge are slowly moving away from each other. The ocean floor to the east of the ridge is a rough mirror image of the ocean floor to the west of the ridge. On your profile mark the mid-Atlantic ridge with an arrow and label it with its name.

   b. At about what distance from North America would the youngest rocks be found on the ocean floor?

3. a. What geologic feature is found about 1010 km East of the mid-Atlantic ridge?

   b. What geologic feature is about the same distance west of the ridge?

4. a. What is the difference in height from the lowest to the highest points shown on your profile?

   b. What is the horizonital distance between the highest and lowest points?

5. a. A guyot (gee-oh) is a flat topped seamount. Label a guyot on your profile.

   b. What is the suspected cause of the flat top?

6. What would be one way in which you could obtain a more detailed profile of the bottom of the Atlantic Ocean?

NAME ____________________

DATE ________ PERIOD _____

PROFILE A: CAPE COD TO MID-ATLANTIC

POINT	DEPTH (M)	DISTANCE (KM)
1	0	0
2	200	120
3	2700	200
4	3700	400
5	4400	440
6	4400	480
7	3700	490
8	4400	500
9	4600	560
10	1600	580
11	4600	600
12	4600	640
13	1800	660
14	1800	680
15	3700	690
16	2700	700
17	4600	725
18	4800	1375
19	3700	1390
20	4800	1400

NAME____________________

DATE__________PERIOD___

PROFILE A: CAPE COD TO MID-ATLANTIC

POINT	DEPTH (M)	KISTANCE (KM)
21	4900	1850
22	3700	1875
23	4600	1890
24	4400	2075
25	1800	2090
26	4400	2100
27	4400	2210
28	4000	2420
29	3500	2440
30	4000	2450
31	3500	2850
32	3100	2900
33	2700	2960
34	1800	2975
35	2200	3060
36	4000	3075
37	4000	3090
38	2400	3100
39	1800	3190
40	2900	3200

NAME________________________

DATE__________PERIOD______

PROFILE B: MID-ATLANTIC TO GIBRALTAR

POINT	DEPTH (M)	DISTANCE (KM)
1	3100	2900
2	2700	2960
3	1800	2975
4	2200	3060
5	4000	3075
6	4000	3090
7	2400	3100
8	1800	3190
9	2900	3200
10	3500	3525
11	2700	3540
12	3500	3550
13	2700	3625
14	2400	3630
15	3700	3640
16	4000	4025
17	900	4035
18	2700	4050
19	1800	4090
20	+ 500	4100

NAME________________________

DATE____________PERIOD____

PROFILE B: MID-ATLANTIC TO GIBRALTAR

POINT	DEPTH (M)	DISTANCE (KM)
21	2200	4110
22	2700	4190
23	4100	4225
24	4400	4425
25	4600	4500
26	4800	4750
27	5100	4760
28	5100	4770
29	4600	4780
30	4400	4825
31	4200	5150
32	200	5160
33	4200	5170
34	4400	5390
35	4600	5625
36	4000	5675
37	3700	5875
38	2700	6050
39	200	6075
40	0	6100

TEACHER BACKGROUND - World's Smallest Ocean

While the previous activities have provided opportunities for constructing and studying bottom profiles, experience indicates that many students still have considerable difficulty in visualizing the bottom from the plotted data. "World's Smallest Ocean" provides an opportunity for a 3-D experience with ocean features.

Duplicate the activity pages. One set is recommended per student. Although this activity can be a bit messy, the rewards are worth the spilled flour and paper clippings on the floor. The activity is best accomplished by pairs but the use of larger groups is possible. It is also possible for individual students to complete the activity. The student procedure suggests the use of baker's dough for modeling the ocean floor. Other materials including plaster of Paris, modeling clay, and play dough are possible. Your class may wish to experiment with other alternatives. Shoe box oceans may be exchanged within the class or between classes. Both techniques have merit. Use the one that best suits your particular circumstances.

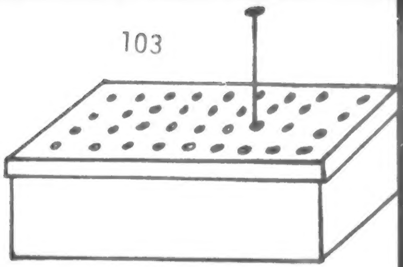
The second day activities provide the major learning experiences. The mechanics of the second day activities are simpler than the directions might seem to indicate. You can minimize problems by a brief introductory demonstration. Have a completed box available as a model. Caution your students to keep their models simple. Choose a technique for punching the holes in the grid that will not result in injury to your students. A sample stand-up ocean model will simplify the last portion of the activity. Circulate through the lab as your class performs this activity. Anticipate any special problems your class might encounter and move to minimize or eliminate them. Allow time for a discussion of the procedure and to provide answers to the questions posed in the activity. Arrange to display your students' stand-up models. Be sure the models are labeled with student names and with the names of the ocean features shown.

KEY

1. The answer depends upon the features present in the shoe box ocean.
2. In spite of what most of your students may feel, they could indeed have missed a feature. If the feature ran between the sampling points it could have been misssed.
3. Small and/or long, thin features would be the easiest to miss.
4. a. A long stick calibrated in some convenient units could be used to measure the depth by simply poking the stick straight down until it reaches the bottom. The depth is read at the intersection of the water surface and the stick. Earliest soundings employed this technique. The technique was quickly modified by substituting a weighted line for the stick.
   b. The major disadvantage of using a probe involves the length of the probe. A 5000m long probe could be a bit unwieldy.
5. Two alternative ways to get information about the bottom of the ocean include: sounding with a rope or cable, echo-sounding or sonar, and/or visiting it in a submersible. Your students may have other, more creative, alternatives.
6. A probe with a hollow end (like the soda straw used in the activity) could be driven into the surface to determine the bottom composition.
7. a., b. The answers depend upon the experimental results.
8. The simplest way to obtain a better picture of the bottom would be to poke more holes and make more profiles.
9. Early oceanographers obviously did not obtain a completely accurate picture of the ocean floor. The fact that a single sounding might take the better part of a day underscores the problems encountered before the advent of electronic depth finders.

KEY WORDS

abyssal plain
continental shelf
continental slope
features
grid
intersect
interval
navigators
probe
ridge
stand-up model
tab
trench



WORLD'S SMALLEST OCEAN

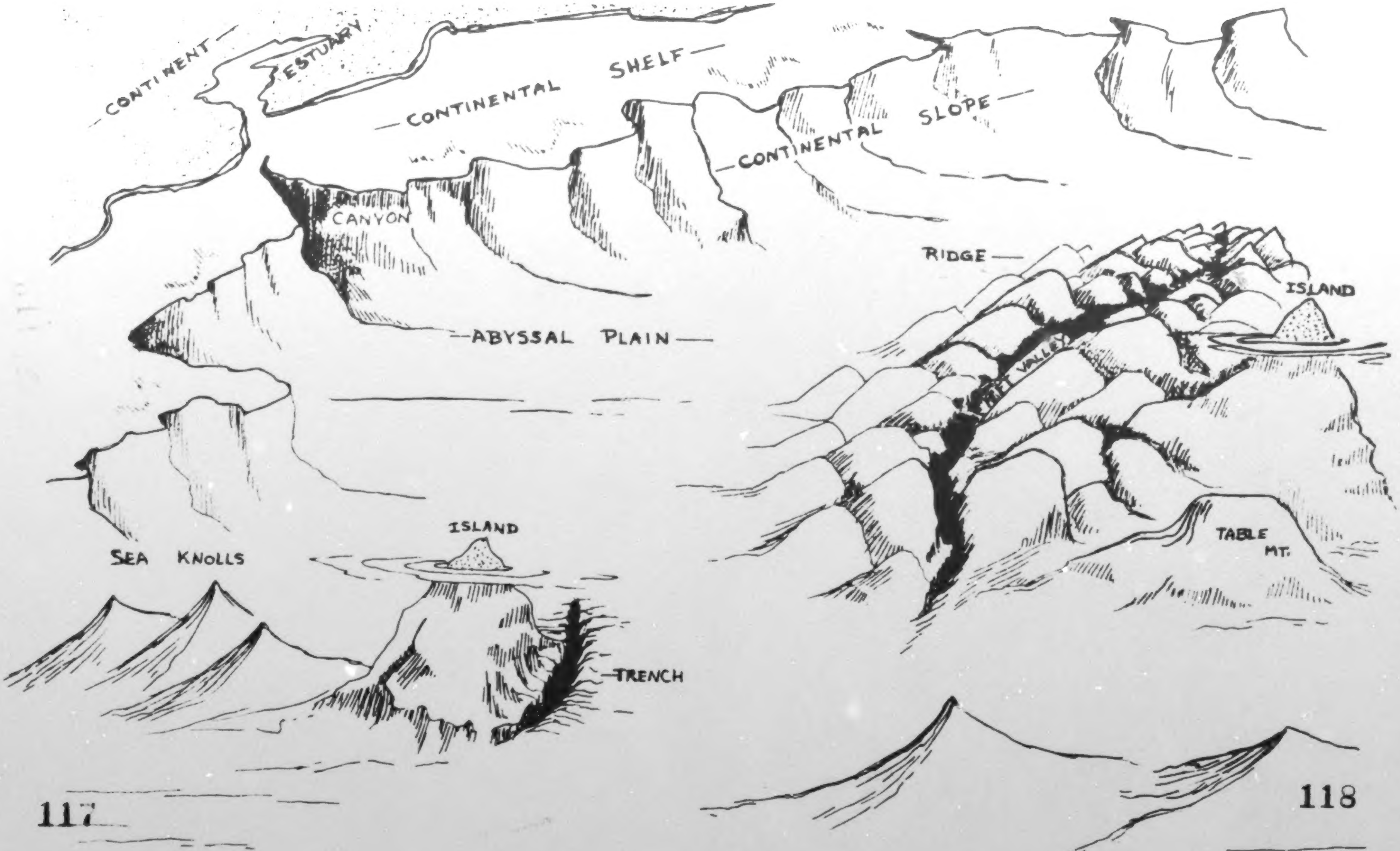
Oceanographers have discovered the shape of the ocean floor by measuring the depths of the water. Because of the great depths, these oceanographers can not see the bottom where they are working. They have to sense the bottom by "feel". In the following activity you will make and exchange a shoe box ocean. Using a probe you will then "sound" the depths of your unknown ocean and make a bottom profile. The next page shows some of the landmarks you might see on the ocean floor.

Materials:

Shoe box with lid
500 milliliters (ml) flour*
500 ml salt
250 ml water
Mixing container (eg. 2 pound coffee can)
Plastic soda straw
Graph paper
Felt-tipped pen
Ruler marked in centimeters (cm)
Pencil, compass or scissors
Scissors
Stiff paper
Glue or tape

---

*250 ml = 1 cup


CONTINENT
ESTUARY
CONTINENTAL SHELF
CONTINENTAL SLOPE
CONTINENTAL SLOPE
CANYON
ABYSSAL PLAIN
RIDGE
ISLAND
RIFT VALLEY
TABLE MT.
SEA KNOLLS
ISLAND
TRENCH
JKH

OCEAN FLOOR

From Oregon State University: Marine Science Education Tips

Procedure:

Day 1

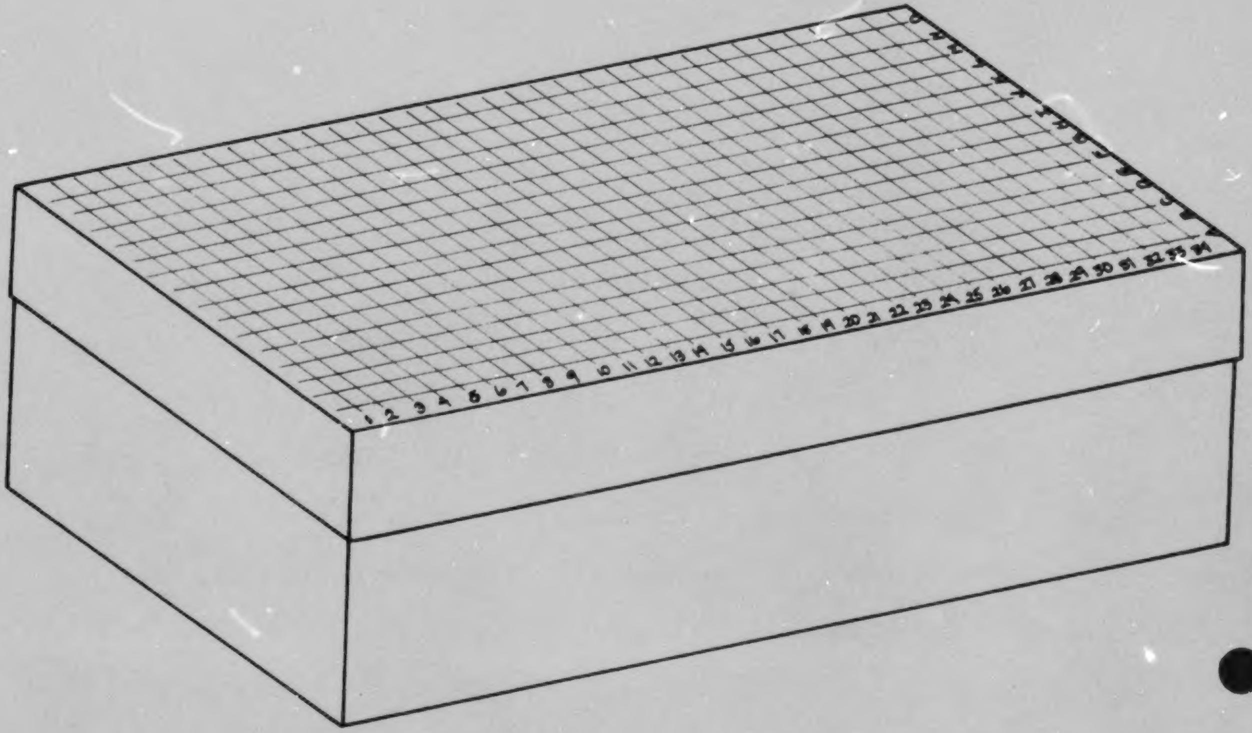
1. Work in pairs. Mix the 500 ml flour and 500 ml of salt.
2. Add the 250 ml of water to the dry mix of flour and salt. Mix well. The mixture should be like a stiff putty.
3. Use the plaster to build a model of the ocean floor in the shoe box. Use the ocean floor drawings as a guide. Keep the models simple (for example, an ocean floor with a mountain or one that has a trench or continental shelf).
4. Put your names on the box.
5. Allow the plaster to dry

Day 2

1. Again, work in pairs. Replace box top and seal with tape
2. Exchange boxes (preferably with another class!). DO NOT open your mini ocean, remember oceanographers cannot see the bottom of the ocean. To get the feel of how an oceanographer works, it is better if you do not see the bottom. When you are all done you will have a chance to see the inside of the box. Record the name on your box and use the same box each day.

3. Mark both short edges of the box at 1 cm intervals. On one side label each mark with a letter beginning with "a" (a, b, c, d, etc.).
4. Connect the marks on the opposite short edges with lines. Mark both long edges of the box at 1 cm intervals.
5. On one edge, label with numbers beginning with "1" (1, 2, 3, etc.).
6. Connect the marks on the long edges with lines. The box lid should now have a grid drawn on the top like the box in the next figure. The grid will be used to locate sample sites on the box.

Each box should look something like this.


1
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34

7. Where the lines intersect (cross), punch small holes (the size of the diameter of the soda straw) with a pencil, compass or scissors. These holes will be the sample sites. You can locate the sample sites by use of letters and numbers on the edges of the top. For example, sample site c-1, c-2, etc.
8. Use the ruler and felt tip pen to mark off the soda straw into 1 cm intervals.
9. Take depth readings (soundings) in the box by inserting the straw straight down until it touches the ocean floor. Record the depth reading in the appropriate space on Data Table 1.

   Note: Make two (2) - that is TWO - copies of your depth recordings. One for you and one for your partner to keep. Reason: If your partner is absent and has the data you will have to start all over again from scratch.
10. On a piece of graph paper draw the apparent cross section of your ocean bottom for row A. Remember zero (0) depth is at the top and the bottom line of the graph corresponds to the bottom of the empty box. Leave a 1 cm wide tab on the graph paper below the bottom of the empty box line. At the bottom of the graph put your names, the box name and row "A". Repeat this procedure for the rest of the rows of data (ie. B, C, D...).

World's mallest Ocean

NAME____________________

Data Table 1

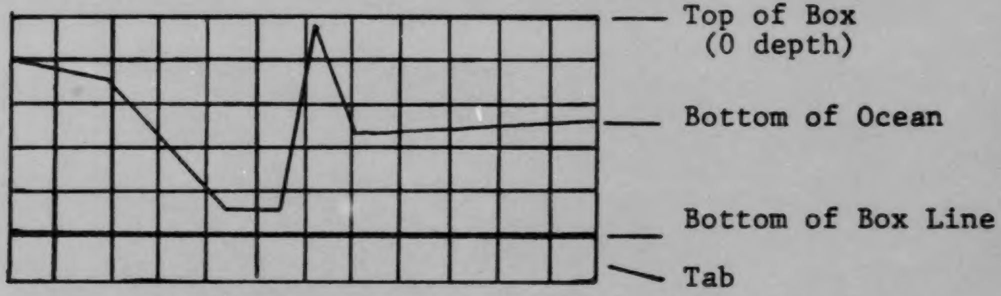
DATE____________PERIOD___

DEPTH MEASUREMENT IN CM

SECTION

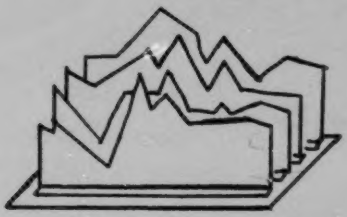
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
A																						
B																						
C																						
D																						
E																						
F																						
G																						
H																						
I																						
J																						
K																						

Your cross sections should look something like this:



11. Carefully cut out each cross section along the curve. Be sure you keep the part which represents the form inside the box.

12. Fold the tab up at a 90° angle along the "Bottom of Box Line" on each graph. Arrange the graphs in A, B, C order and use the tabs to glue or tape them to a stiff piece of paper so that each graph stands up. Your finished model should look something like the picture below.



13. Label your stand up model with the names of ocean bottom features you think are shown.

Analysis and Interpretation:

1. What features are present in your piece of ocean floor?

2. Could you have missed a feature? Explain.

3. What kind of features would be the easiest to miss?

4. a. How could you use a probe to find the shape of the real ocean floor?

   b. What would be one disadvantage of using a probe to measure the real ocean floor?

5. What are two ways (other than a probe) to get information about the bottom of the ocean?

   I.

   II.

6. How could the probe be used to determine what the bottom was made of?

REMOVE THE TAPE AND OPEN YOUR BOX

7. How does your map compare with what is really present?

   a. In what ways is it similar?

   b. In what ways is it different?

8. Other than opening the box, what is one way you could get a better picture of the bottom?

9. The techniques you used are essentially the same as those used by early navigators to chart the depths of the ocean. Do you think they obtained a completely accurate picture of the ocean floor using these methods? Please explain your answer.

TEACHER BACKGROUND - Contours

"Contours" takes the abstractions connected with sea floor topography a final step further. The progression of a profile transect to a series of profile transects in the stand-up models of "World's Smallest Ocean" to contour maps is designed to give your students the skills and background necessary to feel and be successful in the use of bathymetric maps. "Contours" gives your students an introduction to the creation and utilization of topographic maps. The activity culminates with a "self-check" of sorts in which your students reverse the normal process and create a three-dimensional model from their two-dimensional bathymetric map. The maps your students construct will be simple but useful. Supplement their efforts with a display of bathymetric maps, topographic maps, and navigation charts (available from the National Ocean Survey and the U.S. Geologic Survey, or through marine and sporting goods stores).

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished by individual students as an in-class project or as homework after you introduce the topic. Caution your students to use care in the cutting of the cardboard section in Part II. Be aware of potentially dangerous actions as you circulate through the classroom. Allow some time for the students to compare their finished products prior to your discussion of the activity. After your students become familiar with topographic mapping you may wish to have them create topographic maps of the stand-up ocean models they created in "World's Smallest Ocean".

KEY

Part I

1. A correctly labeled bathymetric map is found below.
2. Steep slopes are represented by lines which are close together.
3. The most likely cause of the submarine canyon shown on the map is the scouring action of turbidity currents spawned by the outflow of the Columbia River.

4. Bathymetric contouring is important to captain of the fishing vessel Reckoning, to keep from running aground, and to keep gear from fouling on the bottom.
5. a. While the answer depends upon the class results, it is highly improbable that all of the maps are exactly the same.
   b. The differences may be due to differences of interpretation (does the line go mid-way between the depths, closer to one than the other, etc.) or to errors (missed depths, connecting incorrect depths, etc.). A discussion of the difference between these two types of errors might be worthwhile.
6. Additional depth readings would help to increase the accuracy of this map. They would also increase the difficulty of the mapping.

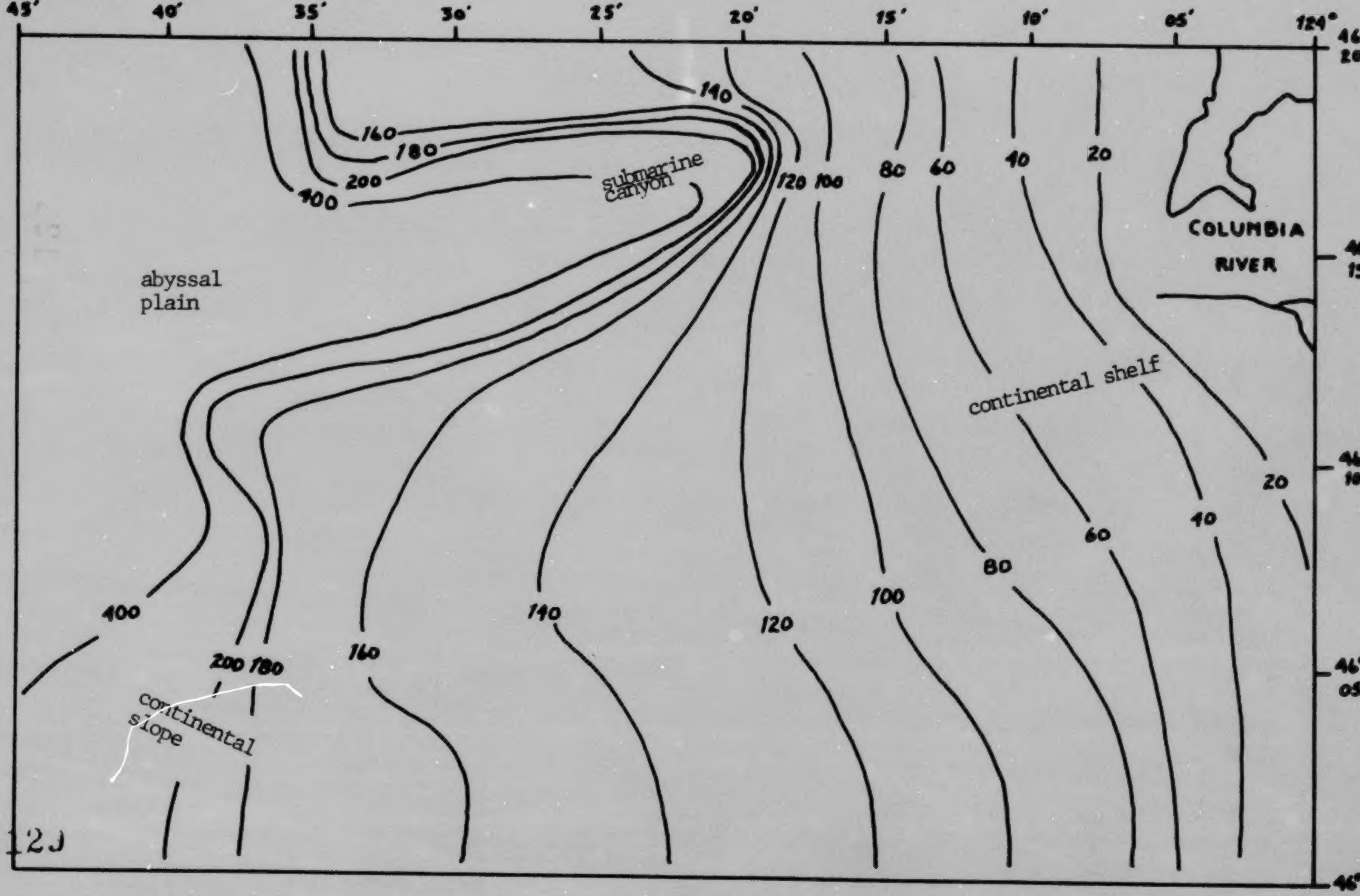
Part II

1. a. Again, while the answer depends upon the class results, it is highly improbable that all of the maps are exactly the same. (If they are, you may wish to look into the well-developed information sharing system existing in your class!)
   b. The same sources of differences seen in Part I apply here: differences due to interpretation and differences due to error.
2. The features labeled may be referenced from the correctly labeled bathymetric map found below.
3. The continental shelf becomes the continental slope at about 200 meters. It might be worthwhile, at this point, to mention that the names we apply to different regions (e.g. shelf, slope and abyss) are somewhat artificial since one blends into the next. The divisions are useful, nonetheless, in helping us understand bottom topography.
4. The continental slope becomes the abyssal plain at about 400 meters.
5. The question asks for student preference. As such, theirs is no right or wrong answer. Most students, however, will find visualization easier with the three dimensional representation.
6. Answers will vary, but most will find the 2-D contour map easier to construct than the 3-D map.

7. The 2-D bathymetric map is definitely easier to store than the 3-D cardboard model.
8. Oceanographers generally use charts because of: a. the ease with which they may be stored, b. the ease with which they may be used, and c. the relative ease with which they may be constructed.

KEY WORDS

abyssal plain
bathymetric maps
charts
compile
continental shelf
continental slope
contour
contour map
data
echo sounder
fathom
representation
sonar
sounding
successive
three dimensional (3-D)
two dimemsional (2-D)


45'
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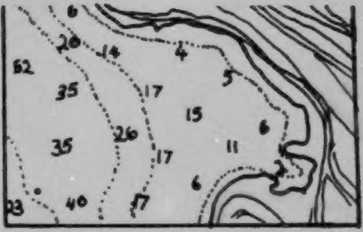
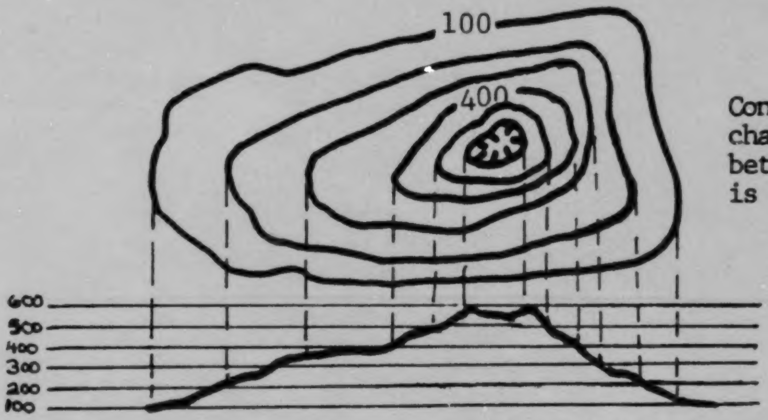
10'
05'
124°
46° 20'
46° 15'
46° 10'
46° 05'
46°
COLUMBIA RIVER
submarine canyon
abyssal plain
continental shelf
continental slope
20
40
60
80
100
120
140
160
180
200
400



CONTOURS

With echo sounders, oceanographers have gathered large amounts of data about the ocean floor. How can they arrange this data in a form that is useful? We have seen one technique--the side view bottom profile. A series of profiles made into a stand-up model gives us a good picture of the bottom. However, the models take a long time to make. They also take up a lot of storage space. To overcome these problems, oceanographers make special contour maps. Contour maps show a three dimensional (length, width, height) surface on a two dimensional (length and width only) sheet of paper. These special contour maps are called bathymetric maps. In the following exercise you will have a chance to make a bathymetric map. Look at the contour map below.



Contour interval (the change in elevation between two lines) is 100 feet.

The map shows how a round hill is shown on a contour map. The bottom figure shows a profile of the same hill along a line from A to B. There are several rules that must be followed in making contour or bathymetric maps.

a. Contour lines are lines of equal height or depth. All points on a given contour line are the same height or depth.

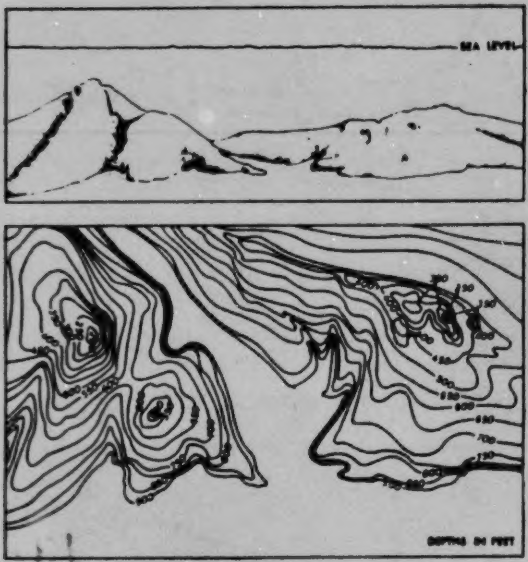
b. Two contour lines may never cross each other.

c. A contour line never ends. Contour lines usually surround a given parcel of land and therefore, form a continuous line.

d. If a line does not surround a parcel of land, it must disappear off the edge of the map.

Contour lines should not make sharp angles. They generally show smooth, regular changes. If one point shows a depth of 1 m and the next point shows a depth of 3 m, the contour line for the depth 2 m must occur between the two points.

Successive contour lines that are far apart on the map indicate a gentle slope. Lines that are close together indicate a steep slope. Lines that run together indicate a cliff. The figure below shows how contour lines express depth and form.



The sketch represents a submarine valley that lies between two hills. In the foreground is a submarine plain. The hill on the right is well rounded and has a ridge extending northwest. The hill on the left slopes steeply and has two peaks. On the map, each of these features is represented directly beneath its position in the sketch by contour lines. The contour lines are labeled as shown. Somewhere on the chart it should be stated whether the units used are feet, fathoms, or meters. A fathom is six feet.

In the following activity you will make a bathymetric map. You will then use the map to make a three dimensional model of a portion of the ocean bottom. The data was obtained near the mouth of the Columbia River.

Materials:

sounding data
pencil
carbon paper
cardboard or tag board
scissors or utility knife
glue

Part I

Procedure:

All soundings on this data sheet are in meters.

1. Obtain a sounding data sheet.
2. Connect equal depth points with contour lines. Begin at a depth of 20 meters. Use a depth interval of 20 meters between contour lines.

3. Add the 400 meter contour line as a dashed line. The dashes show that the interval between the 200m line and the 400m line is different than the other intervals shown.

Analysis and Interpretation:

1. Label the following features on your bathymetric map:
    a) a submarine canyon
    b) the continental shelf
    c) the continental slope
    d) the abyssal plain
2. How are steep slopes represented on your map?

3. What is the most likely cause of the submarine canyon shown on your map?

4. As captain of the fishing vessel Reckoning, you are bound for the mouth of the Columbia river to fish for bottom fish. What are two ways in which bathymetric contouring is important for your safety and success?

    a. ____

    b. ____

5. a. Compare your map with those of others in your class. Are all of the maps exactly the same?

    b. How can you account for any differences you observe?

6. What additional data would help you increase the accuracy of this map?

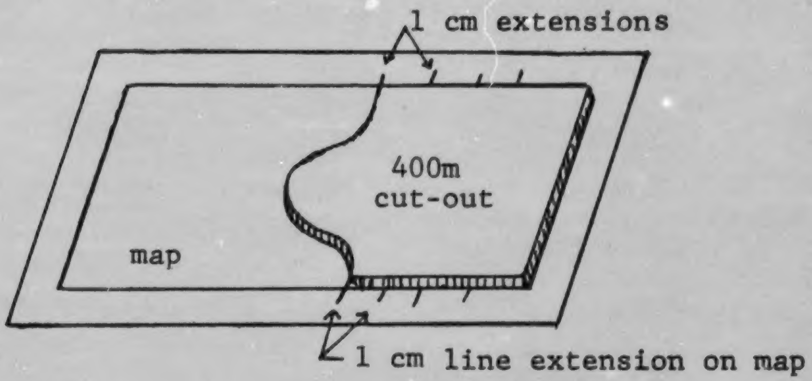
Part II

By now you should have an idea of what the floor of the ocean looks like near the mouth of the Columbia River. In this portion of the activity you will make a three dimensional model to see if your ideas are correct.

Procedure:

1. Obtain 4 or 5 pieces of cardboard or tag board and one piece of carbon paper.
2. Place the carbon paper face down on the cardboard.
3. Place the map you have drawn over the cardboard and trace the 400m contour.
4. Use your scissors to cut along the contour line. Keep the larger piece of cardboard which represents the surface of the earth at a depth of 400m. Label the piece you save "400m" and set aside.
5. Repeat steps 3 and 4 for each of the other contour lines on your map. Be sure to keep the "shore-side" pieces and discard the "ocean-side" pieces.
6. Make a cardboard cutout of the land boundary.
7. Extend your contour lines about 1cm past the top and bottom margins of your map. (By making your contour lines longer, you will be able to tell where to place your cardboard cut-outs).
8. Obtain a glue container.

9. Place the cut-out labeled "400m" over the 400m contour line. If all has gone well, the cut-out will follow the same line and hide all the rest of your map with the exception of the 1cm extensions. It will look something like this:



10. If your arrangement looks like the picture, glue the cardboard in place. Using your extended lines, place the 200m cut-out in its proper position. Glue it in place.
11. Follow the procedure in steps 9 and 10 until you have glued all of the cut-outs in their proper position.
12. Use your model to answer the following questions.

Analysis and Interpretation:

1. a. Compare your map with those of others in your class. Are all of the maps exactly the same?

   b. What are two possible sources of the differences you see?

      1)

      2)

2. Label the following features on your three dimensional model:

   a. a submarine canyon

   b. the continental shelf

   c. the continental slope

   d. the abyssal plain

3. At about what depth does the continental shelf become the continental slope?

4. At about what depth does the continental slope become the abyssal plain?

5. On which of the two representations of the bottom is it easier for you to see the bottom shape?

6. Which representation is easier to construct?

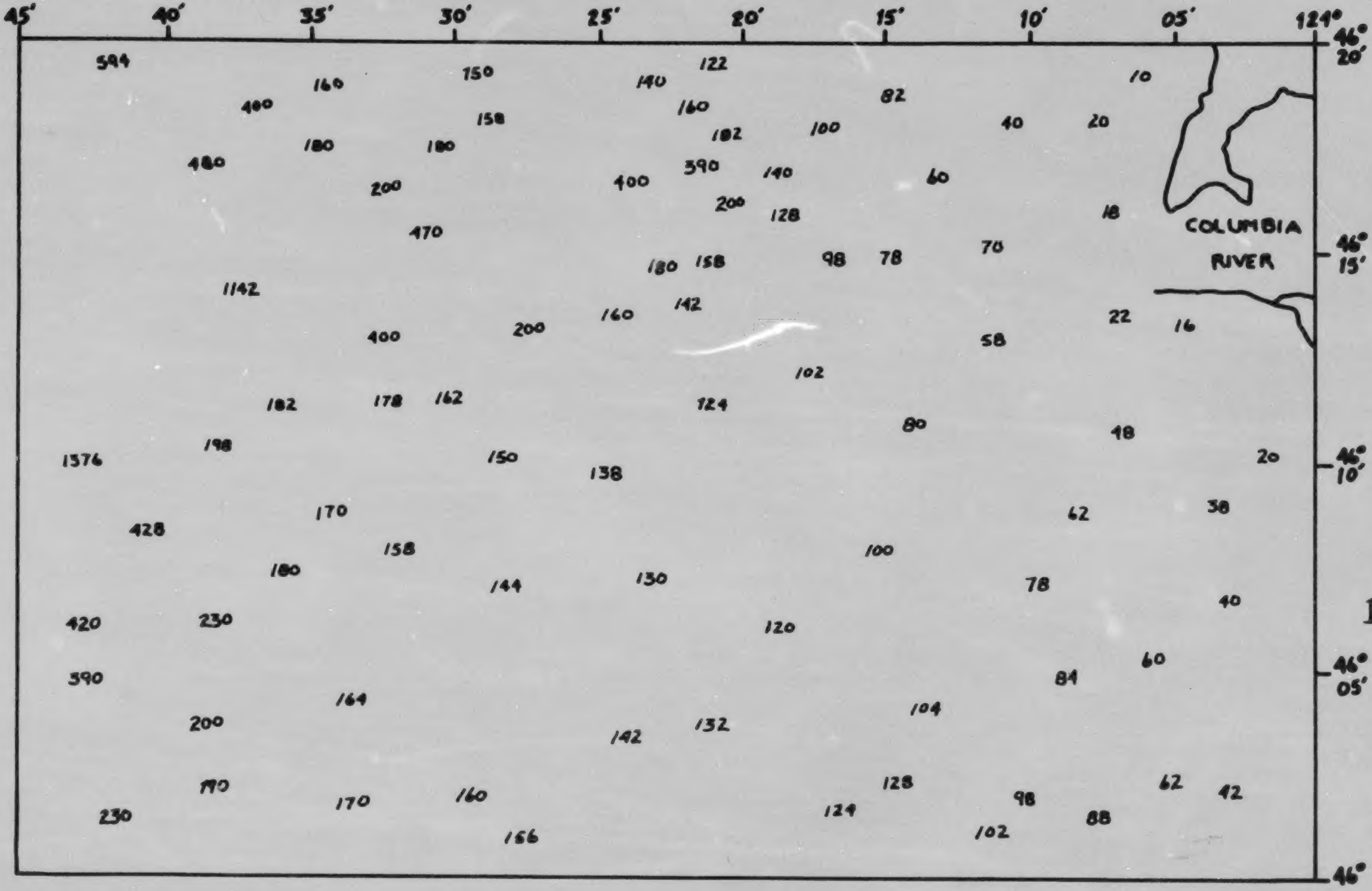
7. Which representation is easier to store?

8. What are two reasons that oceanographers generally use charts instead of three dimensional models to show bottom contours?

   a.

   b.

SOUNDING DATA CHART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COLUMBIA RIVER
594
150
122
140
160
10
400
160
82
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182
100
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20
180
180
480
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166
102

THE HYDROLOGIC CYCLE AND WEATHER

TEACHER BACKGROUND - Water, Water, Everywhere.

Fundamental to the oceans is water. Without water there would be no oceans. There would also be no life as we know it. "Water, Water, Everywhere" provides an activity which furnishs your students with some current thoughts regarding the origin of the water in the oceans. Students often find it difficult to believe that the oceans could be a result of rainfall. The process only makes sense in relation to geologic time, inches of rainfall per year for millions of years can produce a significant amount of water. The other point is that the water that fell as rain started out as water bound in molten rocks. The water escaped when these rocks neared the earth's surface. Unlike today, the rain did not come largely from the evaporation of already liquid surface water. "Water, Water, Everywhere" builds upon the previous activities dealing with geology, plate tectonics, and continental drift.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished in groups of three or four students. The group size is dependent upon the materials available, the number of hot plates usually being the limiting factor. Caution your students that hot glass looks the same as cold glass. Be aware of hot plate use and as you circulate through the classroom watch for potentially dangerous situations. Bringing the soil mixtures to a boil slowly reduces the chances that the mixture will "hump" as large gas bubbles rise to the surface. Encourage a reverence for the earth and provide a waste jar for the soil/water mixture. Do not encourage your students to promote "erosion" by throwing the soil out. Plan to allow time for a discussion of the procedure and to provide answers to the questions in the "Analysis and Interpretation" section.

KEY

1. Answers will vary with the observations. In general, the water begins to move through the soil/water mixture as the mixture heats. Eventually the water will begin to boil and vapor is formed. The surface of the soil is agitated by the heating.
2. a. While the answer depends upon experimental observations, moisture is generally seen on the top of the container (as "fog") and droplets are often seen on the sides as well.

b. Answers will vary, but most of your students will think that the liquid is water. The question calls for an opinion, as such there is no "right" answer.

c. Answers will vary in direct proportion to the creativity of your class. The most obvious way to test if the substance is water is to taste it. This is also the most dangerous way (as you should point out to your students). Other suggestions might include, feeding the water to a plant (or a relative!), a chemical analysis of the compound,(perhaps by electrolysis), and/or checking the properties of the compound against those of water (e.g. specific gravity).

3. The gas most likely released from the beaker model is steam (H_2O). Your students must rely on past experience for the answer to this question since no information is provided about the other gases.

4. The gases condensed on the cool petri dish cover. When the beaker was removed from the heat, the droplets continue to coalesce and eventually fall.

5. While the answers may vary depending upon the observations, the "rain" generally falls from the cover or down the sides.

6. If the earth's surface was hotter than 100°C, any rain that fell would immediately be vaporized and form steam. The steam would rise, form new clouds, condense, and rain again.

7. a. After the surface of the earth cooled below 100°C, any rain which fell would stay on the surface (at least for a while). This question logically leads into a discussion of the water cycle.

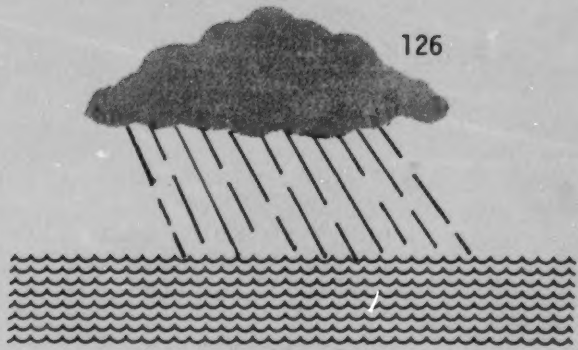
   b. Lakes, seas, and oceans formed in the depressions and low points of the newly cooled crust.

8. This question provides a review and summary for the activity. The water in the oceans came from gases driven off of the earth's surface. The water vapor in these gases condensed in the atmosphere, fell as rain and was re-evaporated. This cyclic process occurring over millions of years helped cool the surface to a temperature below the boiling point of water. Rain which fell after that time could remain as liquid water to fill oceans and seas.

9. Before the depressions could form, the surface of the earth had to cool.
10. Today, as in the past, areas of volcanic activity add new gases and water to the atmosphere.

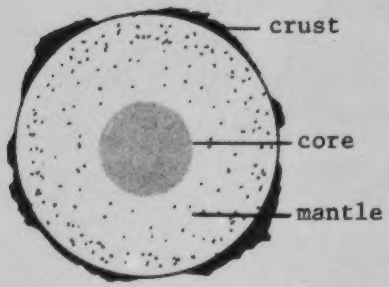
KEY WORDS

atmosphere
boiling point
condensation
condense
core
crust
depression
evaporating
gas
hypothesis
mantle
model
molten
observations
steam
water vapor



WATER, WATER, EVERYWHERE

Over 70% of the earth's surface is covered by water. Life as we know it depends upon water. Where did the water in the oceans originate? Perhaps our new-found knowledge of the earth's geologic history might give us some answers. We know that the earth has a core of very hot molten rock and a mantle of cooler (but still hot) molten rock. A thin, solid layer called the crust covers the surface. Before the crust formed, the entire earth was a sphere of molten rock and burning gases. In the following activity you will recreate the primitive earth and discover from where the water in the seas may have come.



Materials:

- 250 ml or 400 ml Griffin beaker
- soil
- water
- petri dish (top or bottom) or watch glass
- pot holder or beaker tongs
- goggles or safety glasses
- hot plate

Procedure:

1. Obtain a beaker and add soil until it is one-third full.
2. Mix the soil as you add water until you have a thick soup-like substance. Keep the beaker sides (inside and out) as clean as possible.
3. Use a petri dish half to cover the beaker opening.
4. Obtain and wear goggles or safety glasses. Place the beaker on a hot plate and heat gradually for five to ten minutes until the mixture boils.
5. As the mixture boils, use the space below to note your observations about the appearance of the:
   a. soil
   b. the petri dish
   c. the beaker sides
6. After the mixture has boiled for about a minute, use a pot holder to take it off the heat and let it cool. As it cools, note your observations about the appearance of the:
   a. soil
   b. the petri dish
   c. the beaker sides
7. Use your observations to answer the questions in the "Analysis and Interpretation" section.
8. After the beaker has cooled sufficiently, clean up your equipment and work area.

Analysis and Interpretation

1. What happened to the soil mixture as you heated the beaker?

2. a. After heating, what do you observe on the sides and the top of the container?

   b. What do you think the substance you see is?

   c. How might you prove or disprove the hypothesis (your "guess") you stated in part b.?

3. When the earth was cooling from its molten condition it also gave off gases. Our study of active volcanoes today makes scientists believe the earth gave off the following gases:

   carbon monoxide (CO)
   carbon dioxide (CO_2)
   ammonia (NH_3)
   methane (natural gas) (CH_4)
   steam (H_2O)

   Which one of these gases was most likely released from your model beaker earth?

4. As the gases rose from the surface, they began to cool. What happened to the gases from your model earth when they came in contact with the cool petri dish cover?

5. The steam began to cool and form clouds. As the cooling continued, the water vapor in the clouds began to condense. The condensation fell as rain to the still hot surface of the earth.

   Where did the "rain" occur in your model?

6. Water boils at 100° C (212° F). When the earth's surface was hotter than 100° C, what happened to any rain that fell?

7. The process of raining, evaporating, raining, evaporating, etc. continued for millions of years. The earth was gradually cooled to below the boiling point of water.

   a. After the surface cooled to below 100°C, what happened to the rain which fell?

   b. What formed in the depressions and low points of the newly cooled crust?

8. Where, then, did the water in the oceans come from?

9. Before the water could fill the depressions, the the depressions had to form. What had to happen to the surface of the earth before the depressions could form?

10. Where are new gases and water for the oceans being added to the atmosphere today?

TEACHER BACKGROUND - Feels Like Raindrops

"Feels Like Raindrops" provides your students with a look at the influence of the oceans on the hydrologic cycle and weather. Ideally, your students will construct the equipment for a weather station and operate this equipment for several weeks to gather orginal data to use in answering the questions posed. Both the hydrologic cycle and weather deserve more coverage than they have been given in this guide. This material is limited to the effects of the oceans on the hydrologic cycle and on weather. Any good earth science text can supplement the materials found here. The information presented in this activity provides your students with a basic introduction to the concepts involved. Directions are included in the student text for the construction of the various instruments mentioned. While it is quite possible to purchase all of the instrumentation, your students can learn a great deal from constructing the equipment. If you have commercial equipment available, you may wish to supplement the observations made by your students with their hand-made equipment. In this activity be as concerned with the process as with the product. In other words, the weather service can give you better data. The data, per se, is not the most important issue. Getting the data is as important as the data itself.

The pervasive importance of the water cycle is often ignored. A reprint of an article by Courtland L. Smith (which outlines the interrelationships that exist through the water cycle) is included in this Teacher Background.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished by teams of 3 or 4 with each team performing a separate task. The data is then pooled at the conclusion and each student is responsible for the "Analysis and Interpretation" questions. Using this scheme one group would be responsible for making the thermometers, one for making the barometer,etc. Provide each student with a chance to observe the instruments constructed by other groups. Each student should have a copy of the "Weather Record". Having different groups working on different projects will require some extra supervision on your part to guarantee that the work is being performed. Plan to allow time for a class discussion of the procedure and results and to provide answers to the text questions.

KEY - "Feels Like Raindrops"

Text Questions

1. The sources of evaporation shown include: the ocean, soil, ponds, lakes, plants, rivers, and reservoirs. Any three of the above will suffice.
2. The majority of the evaporated water comes from the ocean.
3. Rainfall, falling into the ocean, should be added to the drawing.
4. This question is a check. If your students have been following the logic used in the text, they should have no trouble in recognizing that if the total annual evaporation is 95,000 mi^3 the total annual rainfall must also be 95,000 mi^3.
5. a. This question also checks how critically your students have been reading. 80,000 cubic miles of water evaporate from the oceans in the course of a year. (i.e. Total annual precipitation minus amount evaporated from sources other than the oceans = amount evaporated from the oceans; 95,000 mi^3 - 15,000 mi^3 = 80,000 mi^3.)

   b.

   80,000 mi^3 evaporation from oceans

   +

   15,000 mi^3 evaporation from other sources

   =

   71,000 mi^3 precipitation received by oceans

   +

   24,000 mi^3 precipitation falling on other surfaces

Analysis and Interpretation - Feels Like Raindrops

1. A., B. The answers depend upon the experimental results but should reflect the data gathered by your class.

I., II. The answers depend upon the experimental results. There are some general concepts to be kept in mind. While warm air will hold more moisture than cool air, it may appear that relative humidity decreases with increasing temperature. The specific relationship determined will depend upon the data. The temperature curve and the humidity curve may not be similar enough for a good comparison to be made. If this is the case, a general discussion of the relationship between temperature and humidity may be in order.

III. Ideally, your students should be able to formulate a generalization relating temperature and relative humidity. Increasing the temperature of the air increases the amount of moisture the air can hold. It is possible that the data will make it appear that increased temperatures show lower relative humidities. Since higher temperatures can hold more moisture, their relative humidity could be lower. In other words, a given mass of air will have a higher relative humidity at a lower temperature.

2.; 3.a., b., c., d.; 4. Answers will depend upon the data gathered during the observations on weather.

5. Answers will vary. The kinds of information include the measurements made during the course of the study. While it is difficult to establish the amount of information necessary, it would seem that a minimum of a year's observations would be necessary to develop reliable predictive skills.

6. While the answers will vary, forecasting ability could be improved through the use of more precise instruments, additional instruments and/or information (e.g. satellite pictures!), and data over a longer period for the particular site in question.

Analysis and Interpretation - Making a Thermometer

1. The water level changes when the "thermometer" is exposed to different temperatures because of the contraction and expansion of the water.

2. Since water freezes at 0°C, a water thermometer stops registering change below 0°C. Alcohol or mercury which have much lower freezing points are better choices for the fluid portion of thermometers for use below 0°C.

Text Questions

1. A 12 square inch palm surface is "holding up" 176.4 pounds. This is the logical place for a discussion of air pressure.

2. A falling barometer reading of 30.10 inches indicates rain is likely.

3. Barometeric pressures of 29.8 inches of mercury or less would be expected during a tornado.

4. A rising barometer generally forecasts clearing.

Analysis and Interpretation - Making a Barometer

1. When the air pressure increases outside of the can, the can expands/[✓ contracts] (Circle the correct term)
2. As the pressure increases, the pointer moves up.
3. The pointer moves down when there is a decrease in air pressure.
4. A slowly rising pointer indicates a weather forecast of clearing.

Analysis and Interpretation - Making a Rain Gauge

1. The water is deeper in the jar because the cross sectional area of the jar is less than that of the can.
   This question is designed to do more than test your students' knowledge about conservation of volume. It provides a chance for them to begin thinking about why it is more accurate to read the rainfall in the narrower container.
2. The water is poured from the can into the jar to measure the rainfall to increase the precision with which the rainfall can be measured.
3. Using the large can to catch the rainfall gives a larger area on which the rain can fall. Using the smaller jar to measure the rainfall allows small amounts of rain to be measured accurately because of the fact that a small amount of rain will be measurable on the exaggerated vertical scale.
4. Answers will vary. The distribution of the rainfall over time determines to a large extent the plant populations of a given area. The plant populations in turn determine the animal populations.

Analysis and Interpretation - Making an Anemometer to Measure Wind Speed

1. a. Answers will vary but as the speed of the wind increases, the difficulty of counting the revolutions also increases.
   b. A mechanical counter would facilitate the use of the anemometer.
2. Answers will vary depending upon experimental observations.
3. Low barometric readings (i.e. 28 inches of mercury) are associated with strong winds.

Analysis and Interpretation - Making a Hygrometer to Measure Relative Humidity

1. The water evaporating from the cloth cools the wet thermometer bulb and causes the temperature reading for the wet bulb to be lower than the reading for the dry bulb thermometer.
2. Your students should have numerous ideas regarding sources of error. The two general classifications of error involve errors of observation and mechanical errors of recording.
3. a., b. Answers will depend upon the initial observations but can be easily determined from the chart included in the student pages. These questions are provided to give your students an additional opportunity to use the charts.
4. A decrease in humidity would mean that less water was available to the plant. Less water availability could cause wilting or death.
5. An increase in humidity would reduce the drying risks for the beach-hopper. The beach-hopper would be able to increase its activities and venture in search of food, etc. into areas previously too dry.

Analysis and Interpretation - Making a Wind Vane to Measure Wind Direction

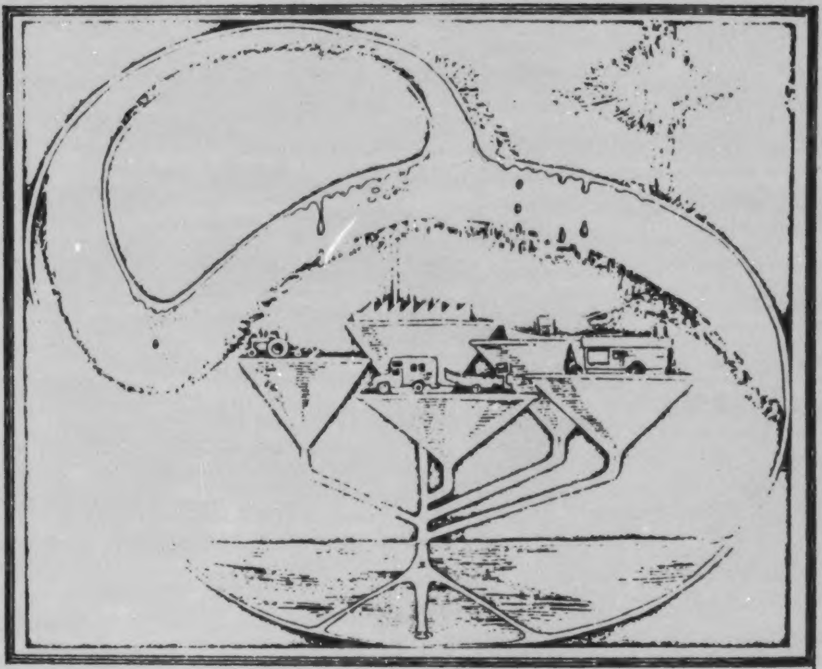
1. The arrow head always points into the wind because the arrow tail is significantly larger than the head and therefore, has a greater wind force against it.
2. Placing the wind vane high off the ground reduces the local turbulence and disruptions caused by trees, buildings etc.
3. a. Winds blowing from the southeast coupled with a rapidly falling air pressure indicate increased probability of winds and rain.
   b. Winds moving west and rising air pressure usually indicate a clear trend with fair skies and cooler temperatures.

KEY

air pressure
anemometer
barometer
calibrate
center of balance
contract
evaporation
expand
forecast
high pressure
humidity
hygrometer
inches of mercury
low pressure
pattern
predictions
rainfall
rain gauge
relative humidity
runoff
temperature
thermometer
tissues
tornado
velocity
weather
wind vane

MAN:

LINKED IN THE HYDROLOGIC CYCLE



Dam construction, now, operates against the urban dweller seeking spiritual renewal and escapc to the seashore.

By Courtland L. Smith

THE HYDROLOGIC CYCLE, run by energy from the sun, moves water from the sea, overland, dropping it as rain or snow on the land. The rain and snow deposited on the land provides water for people to drink, to grow crops, to make consumer goods, water in which to play, to bathe and to toss a pebble.

As water runs off the land, it may seep into the ground to be stored and later removed to irrigate crops in arid inland areas of the Southwest. Crops are irrigated with water as old as a thousand years. Water forms streams and rivers to become a great transportation system. Boating across the United States is possible, with the exception of a 400-mile traverse over the continental divide. Much of this continental transportation system is man-made, but it is fueled by water whose origin was in the sea. The streams, rivers, and waterways also transport natural and man-made wastes from the land back to the sea.

The physical process, the hydrologic cycle, as provider of the water we drink, as a transportation system, and as a bearer of wastes, links man to the sea and the sea to man. More than this, however, it links man to man. It links the picnicker and the commercial fisherman, the valley resident reading the Sunday paper and the coastal resident, the inland resident concerned with flood control and the coastal cottage owner, the logger and the beachcomber, the farmer and the scientist, and so on.

* * *

As an inland resident, I enjoy picnicking along mountain streams as they tumble toward the sea. On one hot windy day, I retrieved my sandwiches from their plastic bread wrapper, judiciously saved to reduce, the consumptive demand on plastic wrapping materials. I set the plastic bag aside, and a gust of wind swept it into a nearby creek. I was naturally displeased with my carelessness and disregard for the environment, and after suitable words of admonishment for my carelessness the incident was forgotten.

Some weeks later, in a conversation with a commercial fisherman, my plastic bag was returned to conscious awareness. The fisherman was telling me that he had recently had to change the refrigeration unit on his fishing boat because the cooling-water intake was too often clogged, lately, with of all things, plastic bags.

I could rationalize that I bore no responsibility for the fisherman's dilemma. The incident had happened several times before the fisherman decided the change was necessary. At worst my plastic bag could have caused only one of these inconveniences. Furthermore, it is virtually impossible to know whether it was my plastic bag or that of some other "irresponsible" outdoorsman. In this case the unknown origin of the plastic bags released anyone from responsibility except the careless group of individuals the fisherman chose to blame. Embarrassed, I did not ask the fisherman who he thought was to blame; I knew at least symbolically who it was.

> *The primary problem with the sugars and sugar derivatives from the pulping process is the increased biochemical oxygen demand, which depletes the dissolved oxygen available for fish.*

Not everyone is a picnicker, but if we investigate the many roles we play, there are many whose impacts we seldom consider because those affected are out of sight and out of mind. Incidents are seldom brought as clearly into focus as was my picnicking and the problem faced by the commercial fisherman.

* * *

All of us are users of paper in one form or another. Paper is used in toweling, toilet tissue, packaging, newspapers and journals. In fact, paper producers estimate that per capita paper usage in the United States is 500 pounds per year. The production of paper provides many wastes which through the hydrologic cycle are carried to the sea. From the logging of the forests to provide wood for pulp, to processing and disposal, paper adds wastes to the streams, rivers and waterways to be carried to the sea.

In logging sedimentation, temperature increases, and organic debris and litter affect the water quality of streams. While forest fires and natural events, too, can cause these forms of pollution, the pollutants which derive from our needs for paper are of sufficient magnitude to affect water quality in localized areas. Most detrimental are the wastes from pulp and paper mills. Pulp and paper mills require large amounts of water. Depending on the process, this has been from 35,000 to 63,000 gallons per ton of pulp. Because of the need for water, pulp and paper mills locate near rivers. When the mill is finished with the water, it is returned to the stream, often with fibers, sugars produced in the pulping and bleaching process, and lignin and, derivatives. The fiber in the waste forms the slime organism, *sphaerotilus*, a filamentous bacterium. This slime has clogged the nets of commercial fishermen and has been of considerable nuisance.

The primary problem with the sugars and sugar derivatives from the pulping process is the increased BOD, biochemical oxygen demand, which depletes the dissolved oxygen available for fish. In the Pacific Northwest, a major paper producing area, salmon are

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reared in fresh water, mature in salt water, and return to fresh water to spawn. Low dissolved oxygen in the rivers kills the migrating fish. Commercial and sport fishermen depend on such rivers as the Columbia and Fraser to provide vast runs of salmon. Partly because of the BOD required by waste products, salmon runs have declined.

Through the hydrologic cycle and complex social and ecological processes, the newspaper reader is linked to the commercial and sports fisherman. The relation is impersonal with one knowing little about the actions of the other. What is the responsibility of the paper user for the net clogging slime and reduced salmon runs? What is his responsibility to the commercial fisherman whose catch is reduced, whose livelihood is threatened? Paradoxically the commercial fisherman, too, is a newspaper reader and consumer of paper products.

If the degree of responsibility could be assigned to the pulp and paper mills, then how much of this responsibility falls on the consumers of their paper products? The responsibility once allocated to each consumer would be so small that it would reach insignificance and become not worth figuring. At least it is not worth figuring from an economic standpoint. Perhaps from a social standpoint the identification of the roles played by those who bear some of the responsibility is important. Tying the links together does implicate the newspaper reader who is perhaps becoming more aware of the pollution problem by reading his newspaper.

The demand for paper products does not always affect only the commercial fisherman. In other contexts the urbanite with his Sunday paper is his own worst enemy as he heads to the seashore to enjoy the sandy beach. In some places the beach is no longer there. Engineers say that damming of the Los Angeles River and other streams, for flood control and power production, has reduced the millions of cubic yards of sand which they once carried that was destined to end up on ocean beaches.

The dams were built to provide water for agricultural and municipal use, to generate the electric energy to power an urban society, and to control flooding of the Los Angeles River and other rivers so people could inhabit the flood plains without fear. The dams were built for and at the behest of the urban residents. Their construction now, operates against the urban dweller seeking spiritual renewal and escape to the seashore.

The hydrologic cycle links man to man. It is a physical process by which the actions of one man affect another even though they are out of sight and out of mind. The hydrologic cycle is such that the actions which meet the needs of a Los Angeles resident for flood protection, electric energy, and water in his household also adversely affect that same individual's interests as beachcomber, sunbather, and weekend coastal resident. The urban resident does not see his actions as president of the local flood control district in any way related to his actions as president of the beach cottage owners' association attempting to save the beach coastwise of his property.

People's attitudes as well as their actions are linked by the hydrologic cycle. One of the aesthetic attractions of the Pacific Northwest beaches is their driftwood. Much of this driftwood was transported to the coast by rivers and streams. Much of the driftwood got in the rivers as a result of careless and inefficient logging practices where poor quality logs were left to the devices of the hydrologic cycle.

One of the favorite activities of Northwest beachcombers, most of whom live inland, is to pick up particularly picturesque logs and wood pieces for display in the front yard, for mobiles in the front hall, or for doing other creative things. The logs which are not selected for preservation in this way become firewood at a cookout, weapons for mock battles, or part of a dwelling hastily constructed for protection from the oncoming squall.

The aesthetic attractiveness of driftwood depends on the attitudes of the beholder. It is a resource which is born as a pollutant and transported by the hydrologic cycle. With attitudes about safety, the logs are viewed as a threat when tossed wildly by winter storms. Attitudes about economic efficiency and environmental management force the reduction of the volume of waste products and stimulate more careful logging practices. Thus, through the hydrologic cycle the attitudes of the logger, beachcomber, forest manager, and environmentalist each bear on one another's actions.

The farm operator feels threatened by an aroused environmental awareness. He perceives himself as out of sight and out of mind. Farmers have told me, "city people don't know where the food comes from;" "agriculture is taking a back seat;" "urbanites don't understand agriculture made this country."

The farm operator sees his job as having to feed a hungry world. The farm operator's actions are structured by attitudes for maximizing production with minimum cost. Rats, rodents, and insects find the farm operator's field a bountiful ecological niche. Maximum production at minimum cost is jeopardized by these "pests." The farm operator then uses pesticides to rid these pests from his farm. Rain washes the residues of the pesticides into the rivers and streams. They become part of the food chain and soon scientists find DDT, methylmercury, and other substances widely distributed over the earth.

Research shows that DDT results in soft-shelled pelican eggs, reduces the tolerance of salmon to temperature differentiation, and even may affect the ability of plankton to participate in the process of photosynthesis. Methylmercury has been described as an ideal "manicide." It acts on man's most vital organ, his central nervous system.

The farm operator had no intention of harming the pelican or other men. He never thought the pesticide he was putting on his land would affect others, and he is critical of other people telling him how he can use his land. He is told what his responsibility is, but no one tells him how to adjust to the higher costs of new, less damaging controls for insects and pests. Further, the sea and pelicans are very far off and not of direct concern to him.

> *To say that everyone shares the blame is to diminish the responsibility such that it is truly insignificant and no action is taken.*

Is the farm operator solely responsible? Farm operators were the major users of DDT, other chlorinated hydrocarbons, and alkylmercury fungicides, but paper mills, plastic industries, and mining operations also use mercury which is broken down by biological means into methylmercury.

What responsibility for causing mercury pollution does purchase of a plastic toy, bearing the signature "Made in Japan," contribute to the problem? In a free market system the consumer has the right to express his tastes in the market place. He creates a demand which following the market links back to the producer results in mercury wasted in streams and rivers.

The hydrologic cycle and food chains get mercury into the diet of man. The purchaser of the toy cannot know whether the plastic for the toy was manufactured by the Japanese company whose mercury pollution had led to 181 people, most of them children, being debilitated from mercury poisoning, 52 people having lost their lives. Clearly the expressions of consumers can alleviate as well as aggrivate pollution problems.

Action on pollution requires knowledge about who pollutes, how much they pollute, and can they clean it up. Action has to deal with the person who is responsible for the effect observed. But who is responsible for the DDT, mercury, and other problem producing substances transported by the hydrologic cycle from one person's outfall to another's intake? Is the farm operator, the manufacturer, or the consumer responsible? Or do they share responsibility? If they share the responsibility, who should do what to correct the problem? Is it right to tell a man how he can use the things which are his? Is it right for an American to express a demand for a product which results in debilitation of Japanese children? After all, one toy, the impact of that one decision, is insignificant.

The hydrologic cycle, then, not only links men in the sense that actions of one person can affect the actions of another. The hydrologic cycle brings together people with different attitudes about right and wrong, good and bad. It can link nations with different philosophies about pollution and how much pollution can be tolerated. Still in terms of conscious awareness we do not see ourselves related to the Japanese pollution problem. We do not see why the independence of the farm operator has to be limited for the sake of the commercial fisherman.

I am not building to the cliche that because we are all consumers, we are all responsible for pollution. This fact is obvious and does little to solve the problems created by man-to-man links established through the hydrologic cycle and processes related to it.

To say that everyone shares the blame is to diminish the responsibility such that it is truly insignificant and no action is taken. It is an oversimplification which fails to recognize the social complexity of the problem. The social complexity of the problem demands that the complex set of social relationships between picnicker, commercial fisherman, farm operator, consumer, etc. be taken into account, and that the diversity of attitudes and goals be taken into account as well. Solutions have to be fitted to dynamic social systems where there is a diversity of actors, actions, and attitudes.

To recognize this diversity will not, however, do much to solve the problems which result from the man-to-man links through the hydrologic cycle. The man-to-man relations established through the hydrologic cycle are impersonal, and there is little caring of one for the situation of the other. There is only limited shock value in the fact that Japanese children have been horribly stricken with mercury poisoning. Even seeing their pathetic approach to life on television or in a magazine cannot make us care in the same way we would if we knew the parents or were working with the children. If we can only know of the tragedy, but not really experience it, then something is needed to mitigate against this dilemma.

As a culture, we Americans are very conscious of our rights. These rights are institutionalized in the Bill of Rights. Some have suggested that there ought to be an "Environmental Bill of Rights." The farm operator is quick to identify his rights as a landowner, corporate executives are quick to point to their right to make a profit, and consumers are wakening to their rights for safe and reliable products, accurately labeled. Yet implicit in a right is a responsibility. Where have we written the responsibilities of a landowner in the exercise of his rights of private ownership? Where have we written the responsibilities of the corporation exercising its right to realize a profit? Where have the responsibilities of the consumer been stated?

When responsibilities have been discussed, it is most often in the context of limiting someone's rights. Responsibilities mean increased costs; responsibilities mean constraints on things we would like to do; responsibilities mean thinking of someone else and not thinking of oneself.

Responsibilities are not a popular item for discussion, and establishing a "Bill of Responsibilities" is unlikely to improve man's relation with the sea or with his fellow man in any significant way. Instead detailed analysis of the dynamic relations between social and ecological systems are needed to clearly spell out potential tragedies so that people can see the consequences of their actions as picnicker, newspaper reader, consumer, etc. Only after humanizing the man-environment and man-to-man relationships which too are part of the hydrologic cycle and other ecological processes will it be possible for people to see how they are implicated, and more important, for people to see how their activities are potentially affected.

Courtland L. Smith [illegible] of anthropology at Oregon State [illegible] Oregon [illegible]

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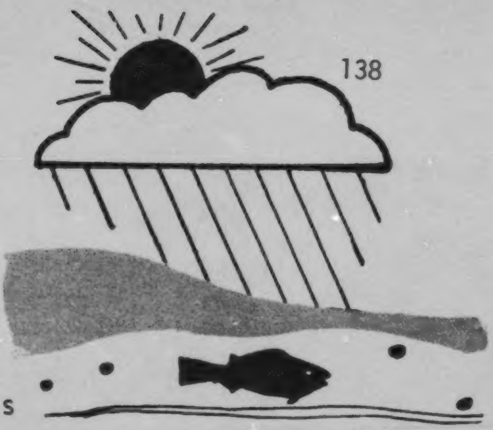
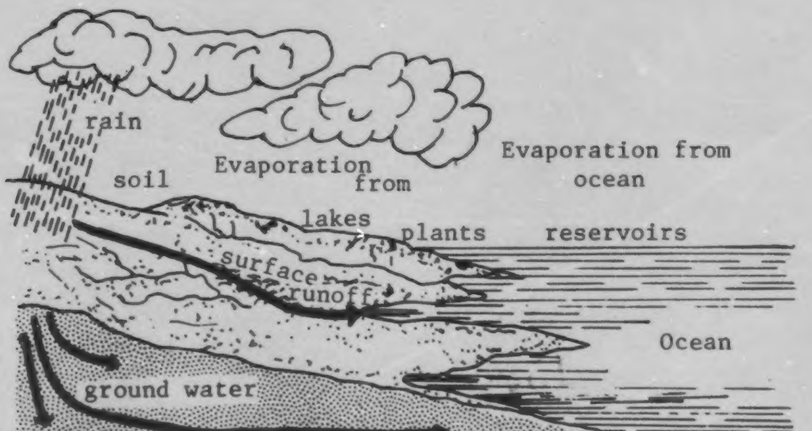


FEELS LIKE RAIN DROPS

The first rainstorms came from water vapor released from the molten surface of a primitive earth. What about today's rainstorms? Where do they come from? What role does the ocean play in weather?

As the sun shines on the surface of the oceans, the water is warmed. Some of this warmed water evaporates. The evaporated water behaves like the water vapor of the primitive earth; it rises. As the water rises, it cools and condenses to form clouds. These clouds build until they can hold no more moisture. At this point, the water falls as rain or snow. Some of the rain falls back into the ocean. Some of the rain and snow falls on the land. A portion of this water flows over the surface while the rest sinks into the ground. The flowing surface water tends to move toward the oceans. The water below the surface also tends to move toward the oceans. If the water does not evaporate on the way to the oceans, it will return to the ocean to be available for evaporation there. This series of events, called the hydrologic cycle or water cycle, is shown in the figure below.



1. What are three sources of water for evaporation?

2. Which source provides the majority of the water evaporated?

3. The drawing is missing rainfall over the ocean. Add this rainfall to your drawing.

The amount of water produced in a year through the action of volcanoes is usually small. Essentially the amount of water on the earth remains the same from year to year. For any year the amount of water evaporating from the ocean must equal the amount of water that falls as rain.

4. If the total annual evaporation is 95,000 cubic miles (mi^3), what is the total annual rainfall?

The hydrologic cycle is actually more complicated than what we have seen. Plants move water through their tissues and give off water vapor. This water vapor is part of the 15,000 cubic miles of water which evaporates each year from sources other than the oceans.

5. a. How many cubic miles of water evaporate from the oceans during the course of a year? (Hint: You know the total annual evaporation and the amount evaporated from sources other than the oceans.)

b. Use the above information and the diagram of the hydrologic cycle to complete the following equation:

________ mi^3 evaporation from oceans + ________ mi^3 evaporation from other sources	=	71,000 precipitation received by oceans + ________ mi^3 precipitation falling on other surfaces

How can you investigate roles of the ocean and water cycle in determining your local weather? The following activities will give you an opportunity to make and use a weather station. A well equipped weather station will have:

thermometers to measure the temperature

barometers to measure air pressure

rain gauge to measure rainfall

anemometer to measure wind speed

hygrometer to measure the amount of water vapor in the air (relative humidity)

wind vane to tell the direction of the wind

Where can you find all of these items? You can make them using the directions that follow. After you collect the equipment, you may want to establish a permanent weather station or you may want to make your daily measurements by taking your equipment out to your measuring site. The following chart will help you summarize your daily weather observations. After you have completed the chart, answer the questions in the "Analysis and Interpretation" section.

WEATHER RECORD

Date & Day	Hour of Day	Amount of Rainfall	Barometric Pressure	Temperature	Relative Humidity	Wind Direction	Wind Speed	Type of Clouds	Probable Weather Conditions
Mon.									
Tues.									
Wed.									
Thur.									
Fri.									
Sat.									
Sun.									

Mon.									
Tues.									
Wed.									
Thur.									
Fri.									
Sat.									
Sun.									

Analysis and Interpretation

1. Relative humidity compares the amount of water actually in the air and the amount the air could hold at that temperature. Temperature and relative humidity must be closely related.

   A. Use the data in your weather record to make a graph plotting temperatures (vertical axis) against day (horizontal axis).

   B. Next use the data in your weather record to make a graph plotting relative humidity (vertical axis) against day (horizontal axis).

      I. How does the shape of the temperature curve compare with that of the relative humidity?

      II. From the graphs, it appears that as the temperature increased during the day, the humidity___________. Conversely, as it got cooler, the humidity_______.

      III. What is the relationship between temperature and relative humidity?

2. a. What kind of weather did you have during the second week?

   b. Look at your air pressure and wind direction data for the second week. What kind of weather would you have predicted using your air pressure and wind information? (See the chart showing "How Wind and Air Pressure May Indicate Weather" in "Making a Wind Vane to Measure Wind Direction").

   c. How does the weather chart predicted by the chart compare with the weather you actually had?

3. a. What was the total amount of rainfall?

   b. What was the *average* rainfall per week? (Hint: This is easy. The average rainfall per week is the total rainfall divided by the number of weeks.)

   c. If the weekly average found in question b. were typical, how much rain would fall in a year (52 weeks)?

d. How does your calculated yearly rainfall compare with your actual annual rainfall?

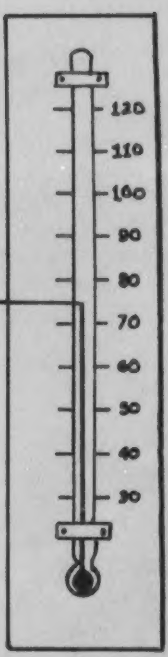
4. Did wind from any particular direction seem to indicate the coming of a storm? If so, what was the relationship?

5. What kind of information and how much information would you require before you put much faith in your weather predictions?

6. How could you improve your forecasting ability?

MAKING A THERMOMETER

A basic piece of equipment for your weather station is the thermometer. Thermometers measure temperature, the hotness or coldness of something. All thermometers work on the basis that things expand when warmed and contract when cooled. Instead of using a standard thermometer, you may wish to make one using the directions below.



Water Thermometer

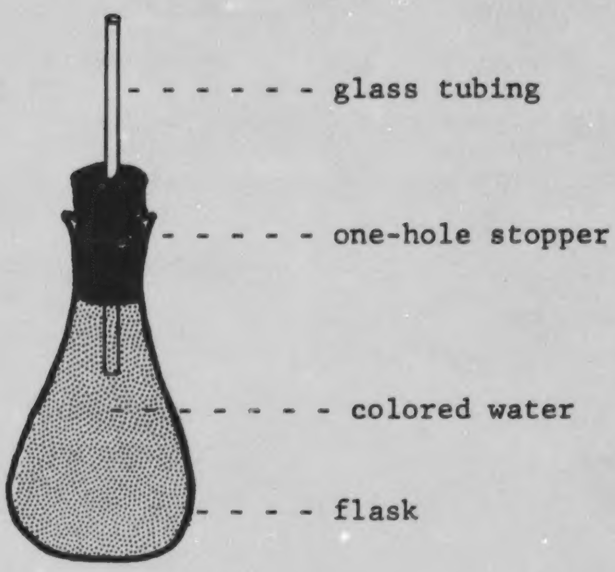
Materials:

Flask (250 ml)
1-hole rubber stopper (to fit the flask)
6 inch glass tubing (to fit the stopper)
Food coloring
Water
Thermometer

Procedure:

1. Fill the flask with water.
2. Add food coloring to make the water easier to see.
3. Using liquid soap or petroleum jelly as a lubricant, fit the glass tubing into the rubber stopper so it barely extends beyond the stopper bottom. Be very careful not to break the glass!

4. Put the stopper into the flask neck as shown in the figure below.

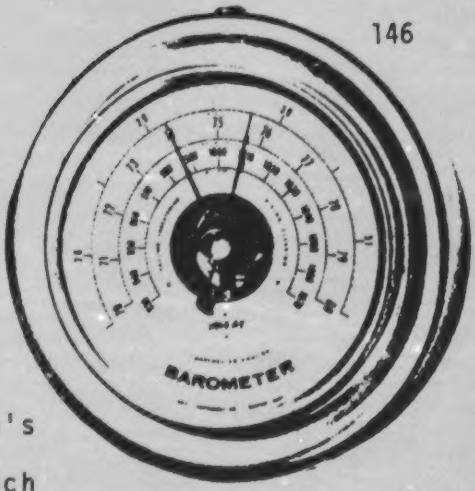


5. Expose this homemade thermometer to different temperatures. Mark the water level for each of these temperatures and label the marks in degrees.

Analysis and Interpretation

1. Does the water level in the glass tube change when the "thermometer" is exposed to different temperatures? Explain why.

2. Why should alcohol or mercury be used instead of water if this thermometer is to be used to measure temperatures lower than 0 degrees Celcius?



MAKING A BAROMETER

A barometer is an instrument that measures air pressure. Air pressure is due to the weight of the blanket of air pushing on the earth's surface. The weight of a one square inch column of air which reaches from sea level to the top of the atmosphere weighs 14.7 pounds.

1. Turn your hand so that your palm is facing upwards. Your palm has a surface area of about 12 square inches. At sea level, how many pounds of air are you holding up with one hand?

You don't feel this weight pushing on every square inch of you for several reasons. The weight is uniformly distributed over your body. More importantly the contents of your body cells are pushing outward with the same pressure. The pressure on the outside equals the pressure on the inside.

What is the relationship between air pressure and weather? Warm air weighs less than cold air. Warm air forms low pressure areas while cold air forms high pressure areas. The movement of these low and high pressure areas results in changes in our local weather. Barometer readings are given in units of "inches of mercury" (For comparison, temperature readings are given in units of degrees). The following barometer readings give an idea of the weather forecast accompanying different barometric pressures.

BAROMETER READING	WEATHER FORECAST
30.1 - 30.2 RISING RAPIDLY	FAIR, RAIN WITHIN 48 HOURS
30.1 - 30.2 STEADY	FAIR, LITTLE CHANGE
30.1 - 30.2 FALLING SLOWLY	RAIN WITHIN 24 HOURS
30.1 - 30.2 FALLING RAPIDLY	RAIN WITHIN 12 HOURS
30.1 or below RISING SLOWLY	CLEARING
30.0 or below FALLING SLOWLY	RAIN FOR 24 - 48 HOURS
30.0 or below FALLING RAPIDLY	RAIN WITH WINDS
29.8 or below FALLING RAPIDLY	STORM WITH STRONG WINDS

2. The TV weatherman announces that the barometer reading is 30.10 inches and falling. What weather change is likely?

3. What would be the approximate barometer reading during a tornado?

4. What type of weather will generally follow a rising barometer reading?

The barometer you will make can be calibrated by comparison with a mercury barometer. If you can not calibrate your barometer, you can use the descriptions on the chart (e.g. rising rapidly, etc.) to predict weather changes.

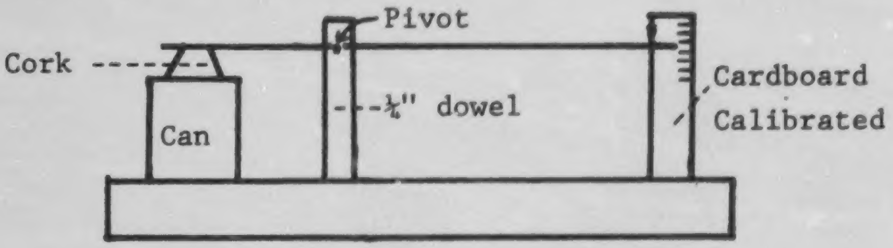
Materials:

small can (similar in size to an evaporated milk can)
wood base 4" x 12" (any available thickness)
balsa strip 12" x 1/8" x 1/8"
sealing wax (if available, some means of soldering)
dowel stick ¼"
cork
cardboard to make a scale
barometer - commercial to use for calibration

Procedure:

1. Seal the holes in the can top with sealing wax or, if available, with a soldering gun.
2. Position the cork on the center of the can top. Next, cement the cork to the top.
3. Place the can on the wood base.
4. Drill a ¼" hole in the base next to the can for the dowel and glue the dowel in its place.
5. Fasten the balsa strip onto the dowel by means of a straight pin while making sure the balsa strip can move freely.
6. Rest one end of the strip on the cork while the other is near the cardboard scale.

7. If possible, calibrate the barometer by using a store-bought barometer.



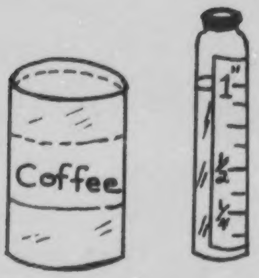
Analysis and Interpretation

1. When the air pressure increases outside of the can, the can expands / contracts (Circle the correct term).

2. As the pressure increases the pointer moves __________.

3. The pointer moves down when there is a ___________ air pressure.

4. You observe the pointer slowly rising. What weather forecast would you make based on this observation?



MAKING A RAIN GAUGE

Rainfall is influenced by the distance to the ocean and by the direction of the wind. You can make a simple rain gauge that will give you an idea of the amount of rainfall during your weather investigation. A rain gauge is used to measure the amount of moisture that falls from clouds. To accurately measure this moisture to within a hundredth's of an inch, it is necessary to use two containers of different size.

Materials:

One large straight-sided can (at least six inches in diameter)

One tall, slender, straight-sided glass bottle (such as an olive bottle)

Masking tape

Ruler

Procedure:

1. Stick a piece of masking tape vertically along the entire height of the glass jar.
2. Pour water to a depth of exactly one inch into the large can.
3. Pour the water from the can into the tall glass jar.
4. Mark the depth of the water on the masking tape and divide the tape, below the mark, into ten (10) equal parts. Label these divisions as tenths of an inch.
5. Set the can outdoors in an open area away from trees and buildings.

6. After a rain, pour the water from the can into the jar and read the amount of rainfall to the nearest tenth or even hundredth of an inch.

Analysis and Interpretation

1. Why was the water deeper than one inch when it was poured from the can into the jar?

2. Why is the water poured from the can into the jar when the amount of rainfall is being measured?

3. Explain why using the large can and the skinny jar together will give you a more accurate measurement of rainfall than using the can by itself.

4. Would you expect areas with ocean breezes to have more rainfall or less rainfall than areas where the air flows off of the land? Why?

5. In general, the distribution of rainfall over time is at least as important as the total amount of rainfall? How does the distribution of rainfall over time affect living things?

MAKING AN ANEMOMETER TO MEASURE WIND SPEED

The pattern of high and low pressure areas on the earth's surface determines the speed (velocity) of the wind. The speed of the wind affects the movement of clouds. It also affects evaporation. In general, the stronger the wind, the more rapid the evaporation. You may have experienced wind evaporation first hand. At a given temperature you will feel colder if a wind is blowing. This is because the small amount of water on you skin evaporates faster in a wind. The device below will let you measure the wind speed at your weather station.

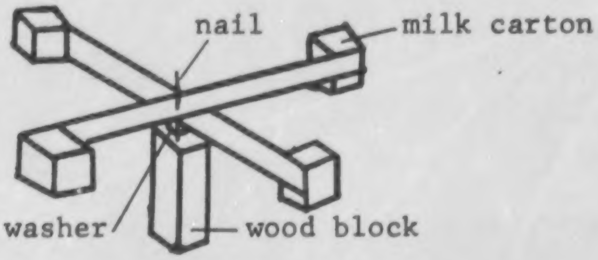
Materials:

four half gallon milk cartons
two 24 inch sticks
short length of wood (e.g. 2"x4"x8")
washers
waterproof glue
electrical tape
finishing nail

Procedure:

1. Cut the tops off of the milk cartons leaving about four inches to the bottom. Make all of the cartons the same size.

2. Mount the milk carton bottoms with some thumbtacks to the pair of sticks.
3. Cross the sticks in the middle and fasten with glue and a piece of electrical tape.
4. Drive the nail into the crossed sticks and move back and forth until the sticks rotate freely. (If a drill and bit are available, you can drill a hole through the sticks).
5. Mount the apparatus on the piece of wood by placing the washers between the cross piece and the block of wood. Drive the nail (through the washer holes) into the block. Your anemometer should look something like the figure below.



6. Calibrate the anemometer by comparing it with your teacher's. You can do this by counting the number of revolutions per minute made by the apparatus at different wind speeds. (Your teacher calibrated her anemometer by counting the number of revolutions per minute made by the apparatus as a friend drove her car at 5 and 10 m.p.h. around an empty parking lot)

Analysis and Interpretation

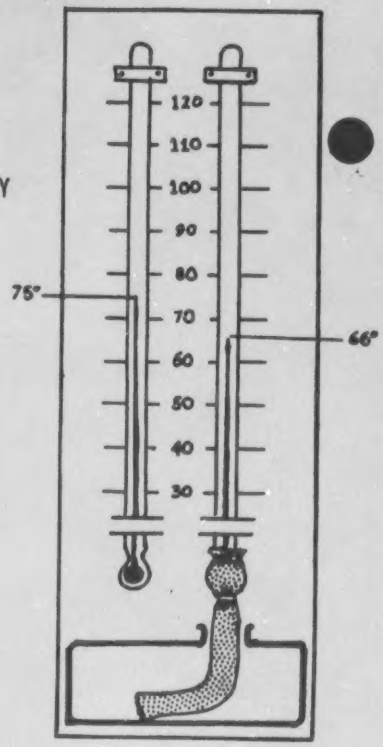
1. a. When you calibrated the instrument, was it hard to count the number of turns?

   b. What would you suggest in order to improve the design?

2. At what speed did you find it impossible to count the number of turns?

3. What kind of barometric readings are associated with strong winds? (Hint: see the section "Making a Barometer").

MAKING A HYGROMETER TO MEASURE RELATIVE HUMIDITY



Relative humidity is a measure of the amount of moisture in the air. The higher the relative humidity the more moisture in the air. Relative humidity is measured in percent. The percentage shows the amount of moisture in the air compared to the maximum amount of moist air that a specific temperature could hold. Relative humidity of 100% usually indicates that it is raining. Very dry locations may have relative humidities as low as 1 or 2 percent. The following activity will enable you to make a wet-bulb/dry-bulb hygrometer to measure the relative humidity at your weather station. The wet-bulb and dry-bulb hygrometer is the most accurate instrument to use in measuring humidity. This instrument is made of two thermometers. One thermometer has a wet cloth around its bulb. The drier the air the more water that will evaporate from the cloth and the lower the wet-bulb temperature will become. The difference in temperature between the dry-bulb and wet-bulb thermometers, along with the dry-bulb temperature, is used in finding the relative humidity on a Relative Humidity Chart.

Materials:

two thermometers (^{0}C)

cloth (1" x 1½" works best)

string or rubberband

water

Relative Humidity Chart

Procedure:

1. Wrap a small piece of cloth once around the bulb of one thermometer. Hold the cloth in place with a string or rubberband.
2. Hold both thermometers so they hang a few inches apart (about 3 to 5 inches).
3. Dip the cloth-tipped thermometer in water to wet the cloth.
4. Fan both thermometers vigorously with a notebook for at least five minutes.
5. Record the temperatures from both thermometers in the Data section.
6. Find the difference between the two readings.
7. Use the Relative Humidity Chart to find the relative humidity. Circle the horizonital line which shows your difference in temperature. Circle the vertical row which shows your dry-bulb temperature. Read the number where the two circles overlap. This number is the relative humidity.

DATA

Dry-bulb temperature: ____________

Wet-bulb temperature: ____________

Difference: __________

Relative Humidity ________________

Difference between dry bulb and wet bulb readings	RELATIVE HUMIDITY (percentage) Dry-bulb temperature (degrees C) 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0.5	94	94	94	95	95	95	95	95	95	95	96	96	96	96	96	96	96	96	96	96	96
1.0	88	89	89	89	90	90	90	90	91	91	91	91	92	92	92	92	92	92	93	93	93
1.5	82	83	83	84	85	85	85	86	86	87	87	87	87	88	88	88	88	89	89	89	89
2.0	77	78	78	79	79	80	81	81	82	82	83	83	83	84	84	84	85	85	85	86	86
2.5	71	72	73	74	75	75	76	76	77	78	78	79	80	80	80	81	81	82	82	82	83
3.0	66	67	68	69	70	71	71	72	73	74	74	75	76	76	77	77	78	78	78	79	79
3.5	60	61	63	64	65	66	67	68	69	70	70	71	72	72	73	74	74	75	75	76	76
4.0	55	56	58	59	60	61	63	64	65	65	66	67	68	69	69	70	71	71	72	72	73
4.5	50	51	53	54	56	57	58	60	61	62	63	64	64	65	66	67	67	68	69	69	70
5.0	44	46	48	50	51	53	54	55	57	58	59	60	61	62	62	63	64	65	65	66	67
5.5	39	41	43	45	47	48	50	51	53	54	55	56	57	58	59	60	61	62	62	63	64
6.0	34	36	39	41	42	44	46	47	49	50	51	53	54	55	56	57	58	58	59	60	61
6.5	29	32	34	36	38	40	42	43	45	46	48	49	50	52	53	54	54	56	56	57	58
7.0	24	27	29	32	34	36	38	40	41	43	44	46	47	48	49	50	51	52	53	54	55
7.5	20	22	25	28	30	32	34	36	38	39	41	42	44	45	46	47	49	50	51	52	52
8.0	15	18	21	23	26	27	30	32	34	36	37	39	40	42	43	44	46	47	48	49	50
8.5	10	13	16	19	22	24	26	28	30	32	34	36	37	39	40	41	43	44	45	46	47
9.0	6	9	12	15	18	20	23	25	27	29	31	32	34	36	37	39	40	41	42	43	44
9.5		5	8	11	14	16	19	21	23	26	28	29	31	33	34	36	37	38	40	41	42
10.0				7	10	13	15	18	20	22	24	26	28	30	31	33	34	36	37	38	39
10.5					6	9	12	14	17	19	21	23	25	27	29	30	32	33	34	36	37
11.0						6	8	11	14	16	18	20	22	24	26	28	29	31	32	33	35
11.5							5	8	10	13	15	17	19	21	23	25	26	28	29	31	32
12.0									7	10	12	14	17	19	20	22	24	26	27	28	30
12.5										7	9	12	14	16	18	20	21	23	25	26	28
13.0											6	9	11	13	15	17	19	21	22	24	25
13.5												6	8	11	13	15	17	18	20	22	23
14.0													6	8	10	12	14	16	18	19	21
14.5														6	8	10	12	14	16	17	19
15.0															5	8	10	12	13	15	17
16.0																	5	7	9	11	13
17.0																			5	7	9
18.0																					5
19.0																					
20.0																					

Analysis and Interpretation

1. What accounts for the difference between readings of the two thermometers?

2. What are two possible errors that could have been made while doing this investigation?

3. What would the relative humidity be if:

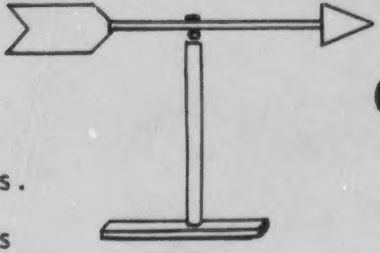
   a. both thermometer readings were 5 degrees higher?

   b. only the dry thermometer reading was 5 degrees higher?

4. How could a decrease in humidity effect a land plant which depends upon the air for part of the water it requires?

5. How could an increase in humidity effect the activities of a small animal called a Beach-Hopper which must keep the outside of its body moist at all times?

MAKING A WIND VANE TO MEASURE WIND DIRECTION



The direction of the wind is determined by the patterns of high and low pressure areas. Observation of the wind directions and changes in directions are used to help forecast changes in local weather. In the following activity you will make a wind vane. The wind vane will help you to tell the direction of the wind at your weather station.

The wind direction is measured by an instrument called a wind vane. Although wind vanes come in many styles, shapes, and sizes, they all have three features in common:

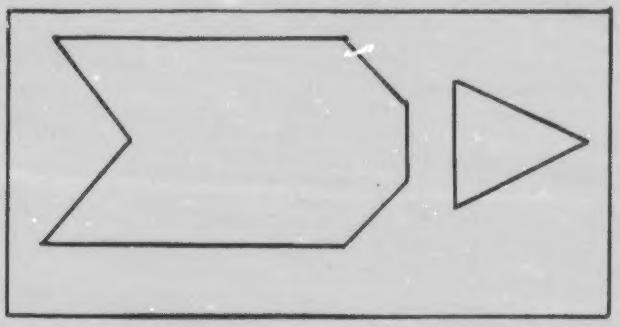
1) They are always well-balanced so they may turn easily in the wind
2) they always have one end about four or five times larger than the other
3) the small end always points in the direction from which the wind is coming. The most common wind vane shape is the arrow described below.

Materials:

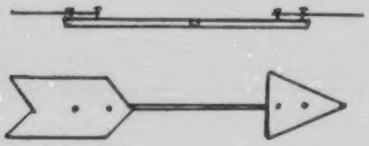
one wooden dowel or block (1" x 6")
one flat wooden stick - 12" long
wooden base (6" x 6" x 3/8")
cardboard, or aluminum pie plate
staples or thumbtacks
washer
nail
directional compass
lubricating oil

Procedure:

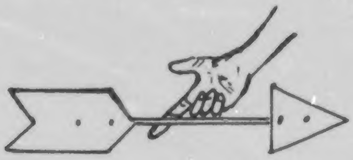
1. Cut out the arrow's point and tail from the cardboard or aluminum pie plate following the pattern.



2. Staple or thumbtack the pointer and tail of the arrow to the stick. (See figure below).



3. Find the center of balance for the arrow. You can do this easily by holding the arrow on the back of your index finger. At the center of balance the arrow will stay without falling or leaning.

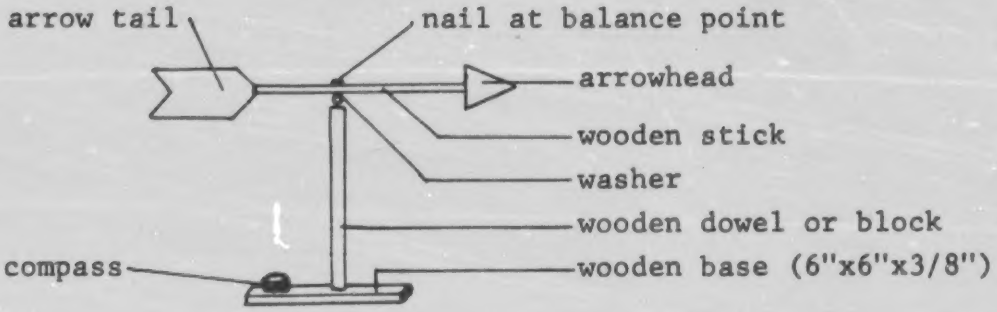


4. Drive the nail through the center of balance of the arrow. Make sure the wind vane can move freely. (If you have access to a drill and bit you can drill a hole in the stick).

5. Place a washer between the wind vane and the short piece of wood, drive the nail into the wooden block.

6. Mount a small compass on the wooden base. The compass will help you name the direction from which the wind blows.

Your finished wind vane should look like the picture below.


arrow tail
nail at balance point
arrowhead
wooden stick
washer
wooden dowel or block
compass
wooden base (6"x6"x3/8")

Assembled Wind Vane

7. Lubricate the nail and washer with a drop of oil so the arrow will turn easily.

Analysis and Interpretation

1. Thinking carefully about how a wind vane is designed, explain why the arrow head always points into the wind.

2. Why is it necessary to locate the wind vane as high as possible from the ground?

3. The combination of wind direction and air pressure let us make better weather predictions than air pressure alone. The chart below shows how wind and air pressure may indicate weather.

HOW WIND AND AIR PRESSURE MAY INDICATE WEATHER

Wind	Air Pressure	Kind of Weather
SW to NW	Steady near 30.1 in.	Fair for 1 or 2 days
	Rising above 30.1 in.	Fair, but rain in 2 days
	Stationary above 30.2 in.	Fair
	Falling slowly from near 30.2 in.	Fair, rising temperature for 2 days
S to SE	Falling slowly from near 30.2 in.	Rain within 24 hours
	Falling rapidly from near 30.2 in.	Increasing winds, rain soon
SE to NE	Falling slowly from near 30.2 in.	Rain soon
	Falling rapidly from near 30.2 in.	Increasing winds, rain soon
E to NE	Falling slowly, but above 30.0 in.	In summer rain within 24 hours In winter rain or snow in 1-3 days
	Falling rapidly below 30.0 in.	Rain soon
SE to NE	Falling slowly below 30.0 in.	Continued rain
	Falling rapidly below 30.0 in.	Rain high winds
S to SW	Rising slowly	Clearing, fair
S to E	Falling rapidly	Storm
E to N	Falling rapidly	Severe storm
Moves W	Rising	Clearing, fair, cooler

a. What do winds blowing from the southeast and a rapidly falling air pressure usually indicate?

b. What do winds moving west and rising air pressure usually indicate?

Optional Activity:

Make another wind vane. This time, use your imagination to design one of a different shape. Don't forget the principles of wind vane construction mentioned above.

ADAPTATION AND DIVERSITY

TEACHER BACKGROUND - Full Court Press

In the previous lessons your students were introduced to the physical setting of the ocean basin. They have examined the shape of the bottom and the forces that have helped cause that shape and filled the oceans with water. In "Full Court Press", your students will have a chance to look at some of the creatures found in the abyss.

The abyss is an uninviting place by our standards. The pitch black waters float near freezing. Tremendous pressures exist. The lack of primarily production (there are no green plants and no sunlight for photosynthesis) severely limits the available food. The consumers living in the abyss depend upon a constant rain of detritus for their food. This rain is supplemented by an occasional large carcass. The inhabitants of this world have evolved an amazing assortment of adaptations to enable them to survive. The following reference provides a thorough introduction to the ocean depths:

Abyss, The Deep Sea and the Creatures That Live In It. 1964. C.P. Idyll. Thomas Y. Crowell Company, New York 396 pages.

Duplicate the activity pages. One set is recommended per student This activity is best performed by pairs of students. The background material may be assigned as homework to be finished prior to beginning the activity. There are some obvious opportunities for flexibility in your choice of materials. For example, rubber balls may be substituted for balloons in Parts A and B. A demonstration of the correct sampling position will facilitate the procedure's use by your students. It is possible to perform the activities on two consecutive days. A logical separation may be made between Part B and Part C. To reduce the number of sets of material you need to provide, you may have half of your class start on Part A and half start on Part C. Choose the approach that will work best for you and for your class. Regardless of the choice, plan to allow some time for a discussion of the concepts involved in this activity and to provide the answers to the text and "Analysis and Interpretation" questions.

KEY

Text Questions

1. a. Your students may require some help in setting up this problem.

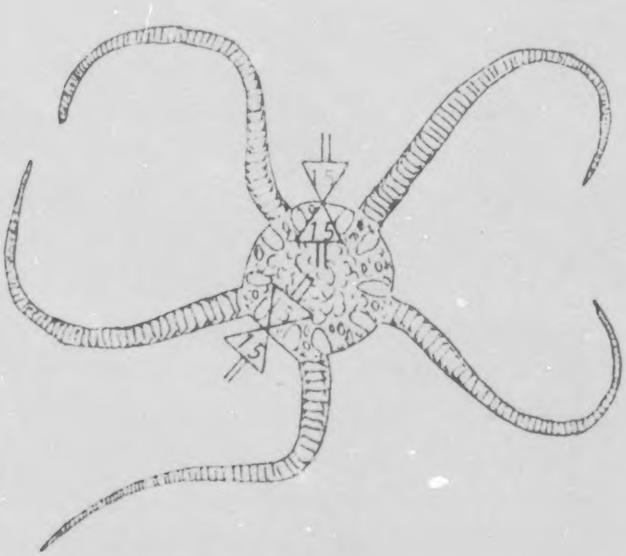
$$\frac{64.6 \text{ pounds}}{\text{foot}^3} \times \frac{30{,}000 \text{ feet}}{1} = 1{,}938{,}000 \text{ pounds/square foot fish}$$

b.

$$\frac{1{,}938{,}000 \text{ pounds}}{1} \times \frac{1 \text{ VW}}{2{,}000 \text{ pounds}} = 969 \text{ VW's}$$

c. Obviously, you would be flattened by the weight of the cars. These manipulations are designed to impress upon your students the magnitude of the forces exerted upon abyssal animals.

2. A correctly labeled deep-sea seastar follows.



DEEP-SEA SEASTAR

3. Abyssal animals are not crushed by the high pressures of the deep sea because the body cells of abyssal animals exert a pressure equal and opposite to the pressure exerted by the water over them.
4. All of the above animals with the exception of the blind lobster have lights. The text states that the angler and the gulper use their lights to attract food. It is most likely that the other animals do likewise. It is worth mentioning that we can only really speculate as to the utility of bioluminescence in these creatures. As mentioned, the light may serve to attract food, it may also serve to attract mates, repel enemies, locate others of the same species, and/or light the way. It may also function in some way as yet unsuggested.
5. The possible reason for the small size of abyssal animals is found in question 4: Food is very scarce in the abyss.

Analysis and Interpretation - Parts A and B:

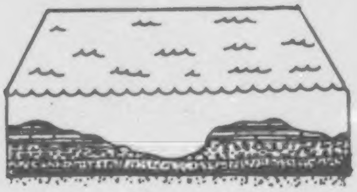
1. a., b. Answers depend upon the experimental results.
   c. The simplest way to make better estimates would be to increase the number of samplings.
2. Answers will vary depending upon the relative success of your students. The kind of sampling your students are imitating is that performed with a dredge or grab. This type of sampling is generally more successful with non-moving or slow moving animals. Swimming or fast-moving animals simply move out of the way of the sampling device.
3. a., b. Answers depend upon the experimental results.
   c. While some of your students may argue for their powers of ESP, there is no convincing way to know whether the sampler missed one color (without removing the blindfold).
   d. The point of 3. c. above is to emphasize the fact the scientists cannot know that they have sampled all of the animals living in the abyss.
   e. Additional samples increase the probability of obtaining individuals from all of the species present in the abyss.

Analysis and Interpretation - Part C:

1. The balloon decreases in size as the jar is lowered into the wash tray.
2. The greatest pressure in the wash tray is at the point of deepest water.
3. The air is compressed by the water. This compressed air outside of the balloon exerts a greater pressure on the walls of the balloon than the air within the ballon exerts on those walls. The result of the greater outside pressure is a decrease in the size of the balloon.
4. In the ocean the greatest pressures are found at the greatest depths. The greatest depths occur in the submarine trenches which are found where one crustal plate slips beneath another.
5. a. If we pushed our balloon animal and jar to the bottom of the ocean, our balloon would be flattened by the high pressures.
   b. We could keep our animal from changing size as we pushed it down by increasing the pressure within the balloon by continually adding pressurized air.
6. Larry couldn't blow up the sunken balloon because his lung power (air pressure) was less than the pressure applied by the water to the outside of the balloon. To fill the balloon underwater the pressure of the air flowing in would have to be greater than the pressure which the water exerts on the balloon.

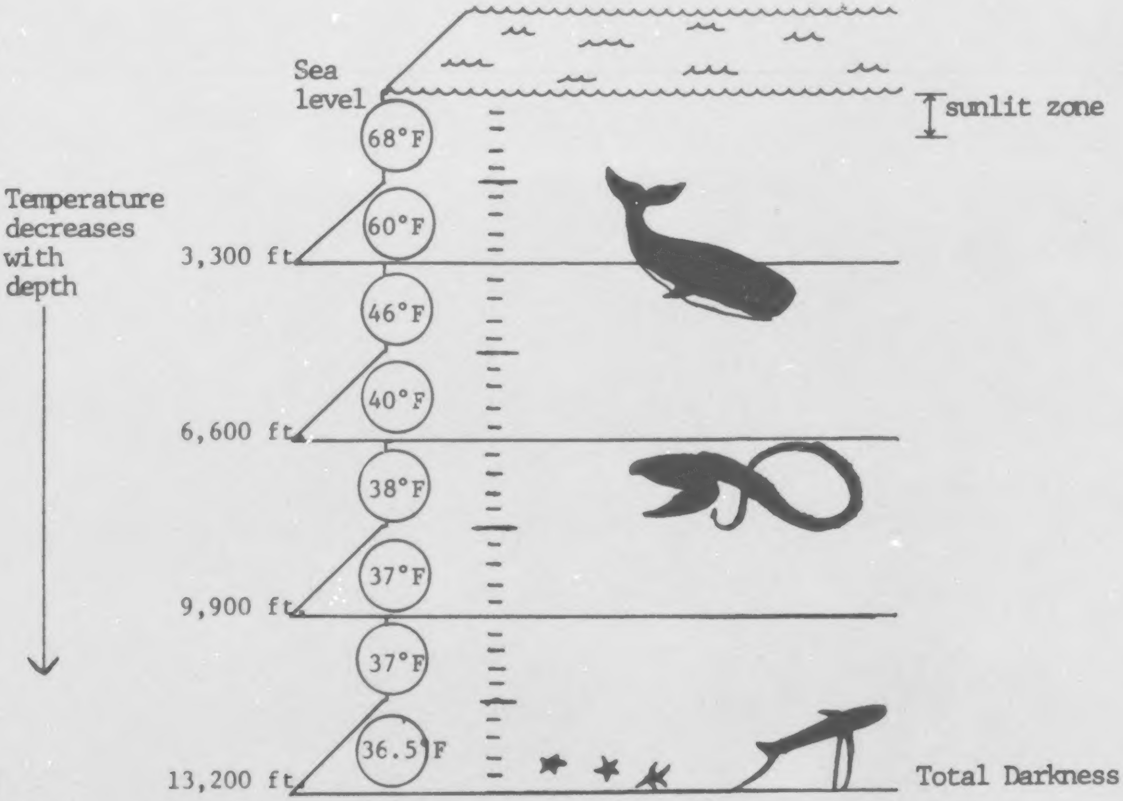
KEY WORDS

abyss
abyssal
adaptations
cell
cubic foot
data
device
dredge
echosounder
estimate
ferocious
glowing
habitat
invert
pounds per square inch
pressure
sample
SCUBA gear
surface area
tentacles
tilt
trench
unique
whisker

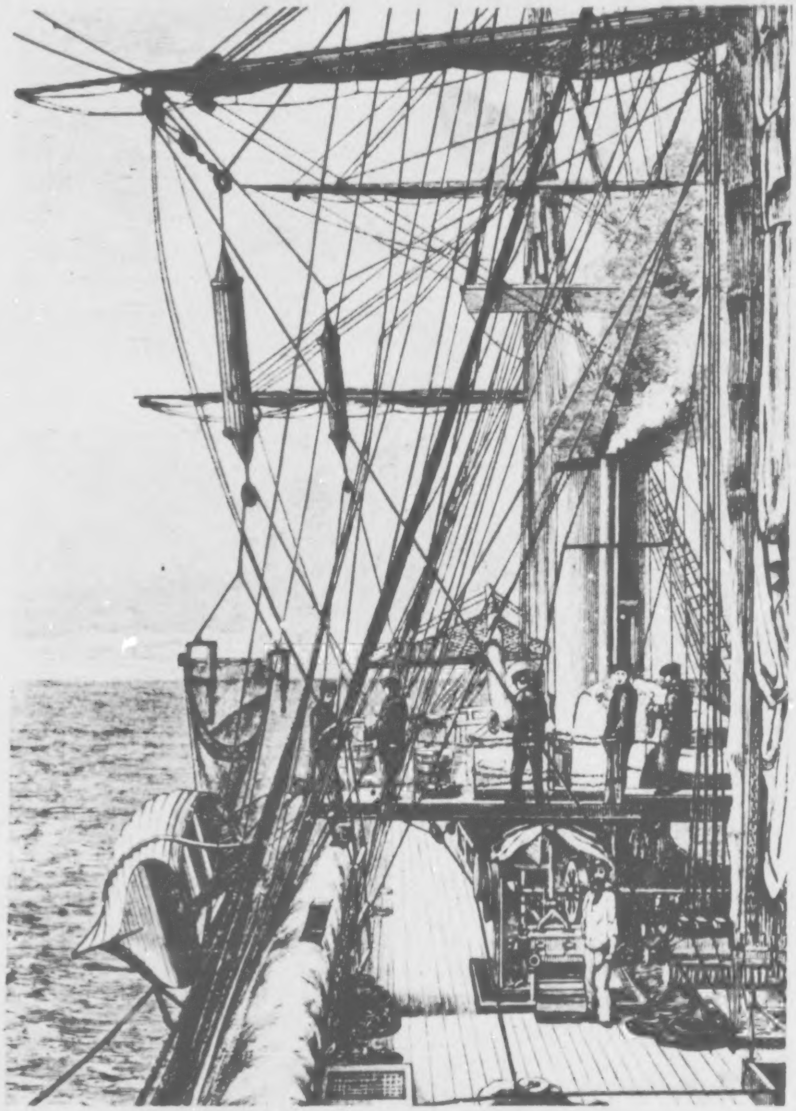


FULL COURT PRESS

The bottom of the deepest trench in the ocean is nearly seven miles beneath the surface. Surely, no life can exist under all of this water. Echosounders let us see the shape of the bottom. Other devices have provided additional information about this totally dark habitat. Temperatures stay just a few degrees above freezing. The downward force of the water creates incredible pressures. Early scientists must have been right, there could be no life on the bottom.

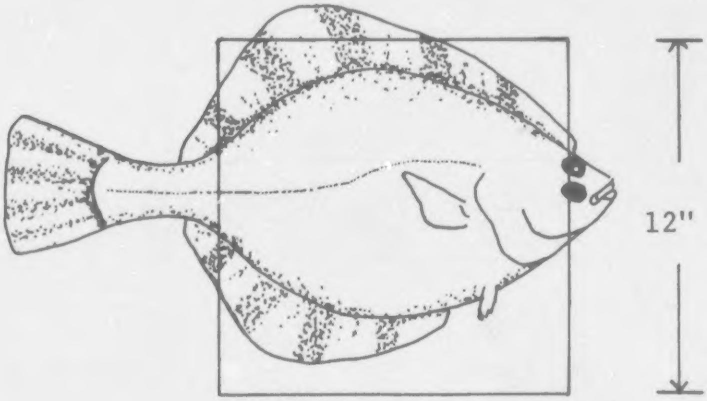

Sea level
sunlit zone
Temperature decreases with depth
68°F
60°F
3,300 ft
46°F
40°F
6,600 ft
38°F
37°F
9,900 ft
37°F
36.5°F
13,200 ft
Total Darkness

So that was that: No life at the bottom. Everyone was happy, or most everyone. In 1872, an assortment of scientists and sailors stood on the deck of the H.M.S. Challenger. They dropped a strange-looking device called a dredge over the side. The dredge soon reached the bottom. It took several hours to rewind the wire attached to the dredge and bring it to the surface. Within a few minutes an old theory died. The mud in the dredge was full of animals and plants.



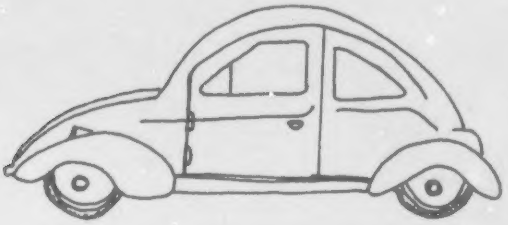
Dredging and sounding apparatus on the deck of the Challenger

Before we examine some of these bottom dwelling creatures, let's look at their habitat or surroundings. The deep-sea floor is always dark. We know the some land animals live in caves which are always dark. Animals can deal with darkness. The near freezing temperatures are no colder than some inhabited land areas. What makes the deep-sea so unique? Pressure. Water weighs 64.6 pounds per cubic foot. This means that an animal with a surface area of one square foot would be subjected to 646 pounds of pressure at a depth of ten feet.



1. The picture above shows a deep-sea fish with a surface area of one square foot.
    a. To how much pressure is the fish subjected at a depth of 30,000 feet?

b. A VW beetle weighs about 2,000 pounds

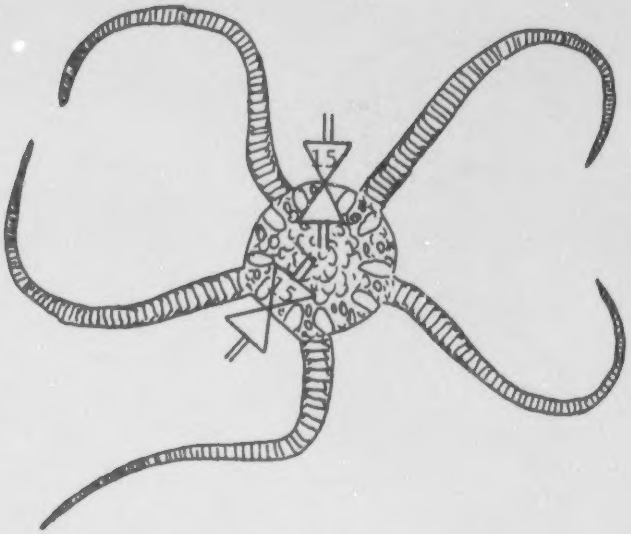


2000 lbs.
1 ton

How many V.W.'s would produce the same pressure felt by fish at 30,000 feet?

c. What would happen to you if that many V.W.'s were on top of you?

Knowledge of these great pressures convinced people life couldn't exist in the deep-sea bottom or abyss. We now know that life does exist there. How does this life deal with the pressures? Abyssal animals are not paper thin from the pressure. The animals deal with the pressure in the same way we deal with air pressure. Air pressure is the weight of the air above us. At sea level the air above us presses down with a force of 14.7 pounds per square inch. This equals 2116 pounds per square foot. More than our V.W. Why aren't we crushed? We aren't crushed for the same reason abyssal animals aren't crushed. Our body cells exert a pressure equal and opposite to that of the air pressure. The body cells of abyssal animals exert a pressure equal and opposite to the pressure exerted by the water over them.

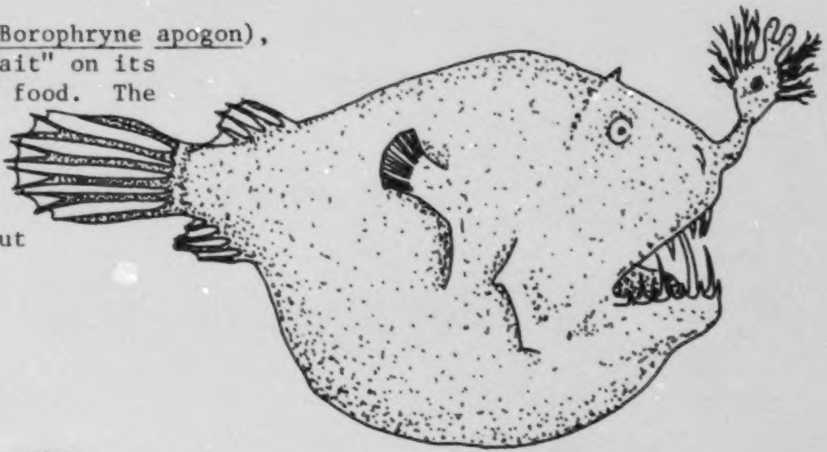


DEEP-SEA SEASTAR

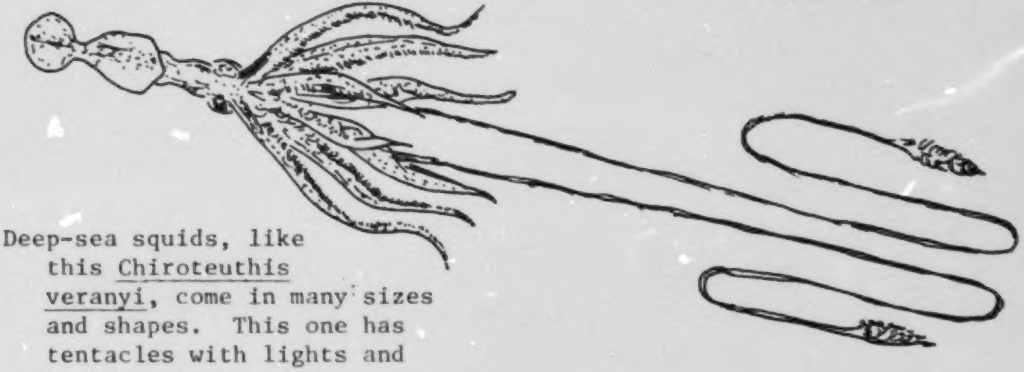
2. The arrows show the pressure within and outside the seastar's cells. Fill in the pressures represented by the blank arrows.

3. Why aren't abyssal animals crushed by the high pressures of the deep sea?

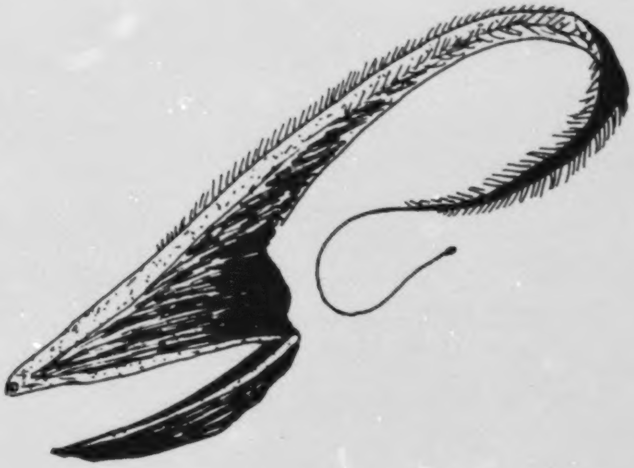
Worldwide, only the animals that are best suited to the place in which they live survive. The animals of the abyss survive in spite of the darkness, the cold and the pressure. These animals have special adaptations to help them survive. Some of these abyssal animals are shown below.



The Deep-Sea Angler, (Borophryne apogon), uses the lighted "bait" on its forehead to attract food. The angler fish is almost as wide as it is long. This ferocious-looking fish is about 7 cm (3 in.) long.



Deep-sea squids, like this Chiroteuthis veranyi, come in many sizes and shapes. This one has tentacles with lights and hooks at their ends.



The Gulper eel, Eupharynx pelacanoides, grows to 60 cm (24 in.). It has a huge mouth which it snaps open. The rapid opening sucks in water and fish. The lighted tip of its tail attracts its food.

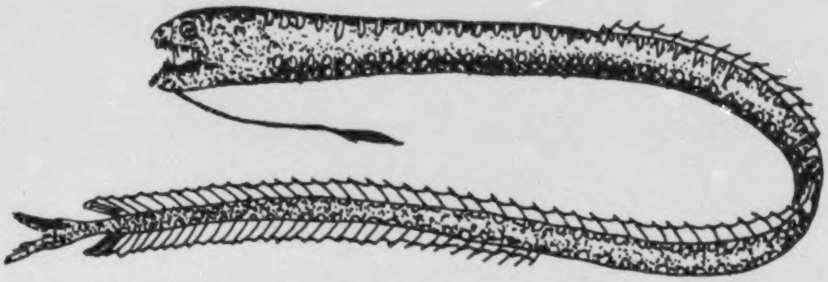
4. Food is very scarce in the abyss. Which of the animals above have lights to attract their food?

5. In spite of the ferocious appearance, most of these animals are less than a foot long. What is one possible reason that abyssal animals tend to be small?

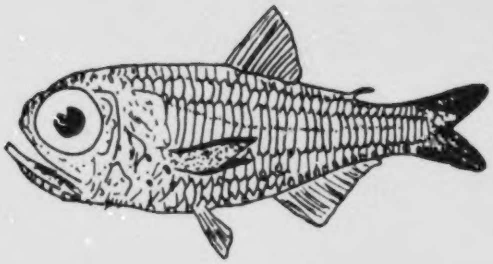
In the century since the Challenger we have learned something about life on the bottom. We still have a lot to learn. It is difficult to sample bottom life. In the following activities you will have a chance to sample "abyssal creatures" and observe the effects of air pressure.

Materials:

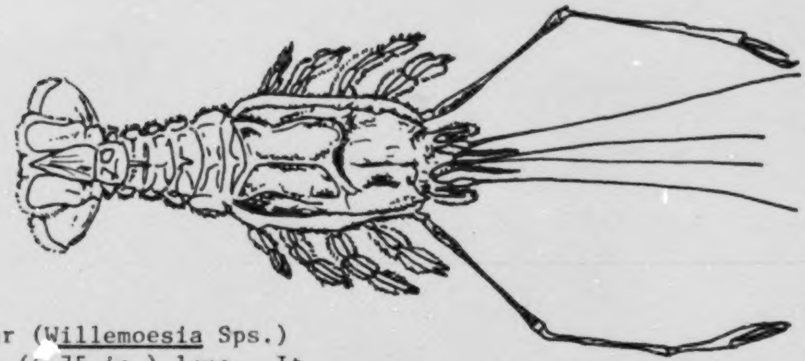
4 round balloons, various colors
plastic wash tray or similar container
blindfold
quart jar, clear
centimeter ruler
water
desk or table
chair



This Stomiatoid Fish, (Idiacanthus panamensis), has a glowing light at the tip of its "whisker." The spots along its 15 cm (6 in.) body glow bluish-white.



This 4 cm (1.6 in.) lantern fish (Electrona rissoi), spends the day in the deep sea. When darkness comes, it rises to the surface. It has a row of dim lights on its sides and bright tail lights.



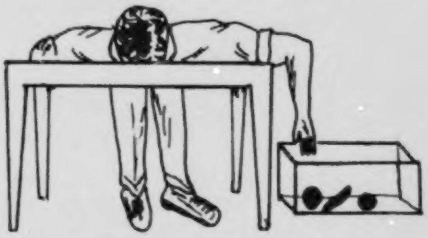
This blind lobster (Willemoesia Sps.) is about 12 cm (4.75 in.) long. It was caught at a depth of 12,173 feet.

Procedure:

Part A - Sampling the Abyss

For this activity you will need to work in pairs. Since you will be blindfolded for part of the experiment, please read through these instructions before you begin.

1. Obtain four round balloons (animals) and inflate them until they are about 2 inches in diameter.
2. Obtain a plastic wash tray. This tray will be your ocean basin. The bottom of the tray is the abyss.
3. Sit at a desk or table. Put the chair next to your desk. Place your arm so that your elbow joint is on the corner of the desk with your forearm hanging down. Use the picture below as a guide.



4. Your partner will now blindfold you.
5. Have your partner place from one to four balloons on the abyssal floor of your wash tray.
6. Your partner will next place the tray on the chair beneath your dangling arm.
7. Sample the abyssal animals (balloons) by making a single, straight-down grab. Make four individual grabs to sample the number of abyssal animals.

Have your partner record the number and color of the balloon animals you capture on each sample. Use the data form below.

Sample Number	Animals Captured	Color
1		
2		
3		
4		

8. KEEP YOUR BLINDFOLD ON. Use your sampling data to estimate (guess) the total number of animals present. RECORD your estimate:_______animals.

9. Have your partner record the actual number of animals present. Actual:___________animals.

Part B - Sampling the Swimmers

1. Most abyssal animals have some way to move. To make things more interesting, repeat the above steps 1-9 with the following addition. Between each sampling, your partner will be able to tilt the tray to change the position of the animals.
2. Have your partner record the number of animals you capture on each sampling. Use the data form below.

Sample Number	Animals Captured	Color
1	________________	______
2	________________	______
3	________________	______
4	________________	______

3. KEEP YOUR BLINDFOLD ON. Use your sampling data to estimate the total number of animals present. RECORD your estimate:_________animals.

4. Have your partner record the actual number of animals present. Actual:__________animals.

5. Exchange places with your partner and perform parts A and B again.

6. Record your partner's data in the form below.

Part A - (Non-movers)

Sample Number	Animals Captured	Color
1	________________	_______
2	________________	_______
3	________________	_______
4	________________	_______

Part B - (Swimmers)

Sample Number	Animals Captured	Color
1		
2		
3		
4		

Analysis and Interpretation:

1. a. Was your estimate of the total number of animals in Part A correct?

   b. Was your estimate of the total number of animals in Part B correct?

   c. If your estimates were not correct, how could you improve your data to make better estimates?

2. Which group of animals, the non-movers or the swimmers is easier to sample? Why?

3. Scientists are interested in more than just the total number of animals. They want to know how many of each kind are present. The different color balloons represent different animals. Look at your data to answer the following questions.

   a. In part A, did your samples contain animals of all the colors?

   b. In part B, did your samples contain animals of all the colors?

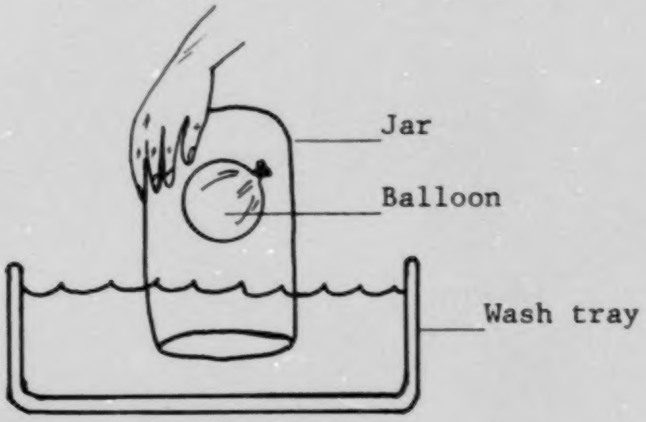
   c. Without removing your blindfold, would you have any way of knowing that you had missed one color?

d. Do scientists know that they have sampled all of the animals living in the abyss?

e. How might additional samples help scientists get a better picture of life in the abyss?

Part C - The Squeeze is On

1. Obtain a clear quart jar.
2. Fill your wash tray about 3/4's full with tap water.
3. Place one of your balloons in the quart jar.
4. Invert (turn over) the jar and balloon. Quickly lower the jar into the water. Your set-up should look something like the drawing below.



5. Hold the jar so that the lip is just below the water surface. Use the centimeter ruler to estimate the size of the balloon. Record the size:________centimeters.
6. Push the jar to the bottom of the wash tray. Use the centimeter ruler to estimate the size of the balloon. Record the size:__________ centimeters.

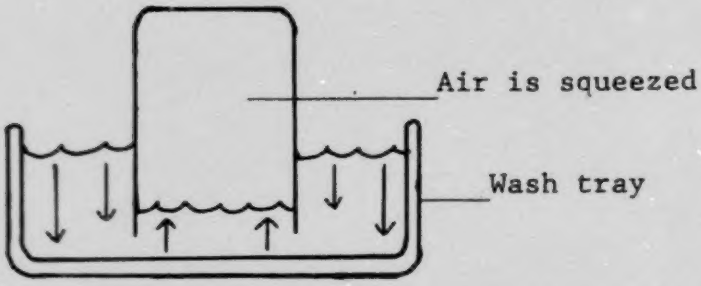
Analysis and Interpretation:

1. What happened to the size of the balloon as you lowered the jar?

2. Where is the pressure greatest in your wash tray?

   (Hint: Remember the pressure is from the weight of the water.)

3. The diagram below shows how the water pressure in the tray squeezes the air in the jar. How does this diagram explain what happened to your balloon?

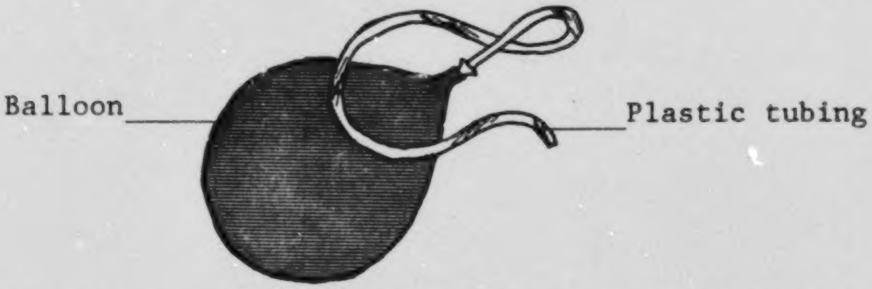


4. In the ocean, where are the greatest pressures found?

5. a. If we pushed our balloon animal and jar to the bottom of the ocean, what would happen to our animal?

   b. How could we keep our animal from changing size as we pushed it down?

6. Larry Lung was experimenting with homemade SCUBA gear. He made the device shown below. Being a bright person, he decided to try it out before diving. He lowered the balloon to the bottom of his swimming pool. He then tried to blow up the balloon.



(His plan was to jump in and breathe through the tube). No matter how hard he puffed, he couldn't blow up the balloon. He's come to you for an explanation. Why couldn't Larry blow up the sunken balloon?

TEACHER BACKGROUND - Return to the Sea

Whales are inherently fascinating to students. Their plight has brought them into the public eye. The following text pages are designed to give your students an overview of whale biology. The whaling issue and attendant controversies are pointedly avoided in this section. They will not be avoided later on. It will be difficult for you to direct the topics of discussion toward cetacean adaptations for survival and away from the topics currently in the media. Make an effort to treat the media topics lightly at this point. You will have ample opportunity to discuss whaling and marine mammal preservation in connection with future activities. For the present, emphasize the unique aspects of whale biology touched upon in this section. A list of teaching resources and a partial bibliography are included at the end of this Teacher Background.

Duplicate the text pages. One set is recommended per student. This activity is best accomplished by individual students as homework or as an in-class activity. After your students have read the text and answered the questions, you might elect to have them meet in small groups to compare answers and arrive at a concensus before you discuss the materials with the class as a whole. Regardless of the approach you select, plan to allow time for a class discussion during which you provide the answers to the text questions. Supplement this activity with audio-visual aids. Check your supplier and also the list found at the end of this section. You may wish to have your students prepare and share brief life histories of selected cetaceans. Recall that this section is a general survey of the group and that additional materials about many of the topics will be provided in future activities.

KEY

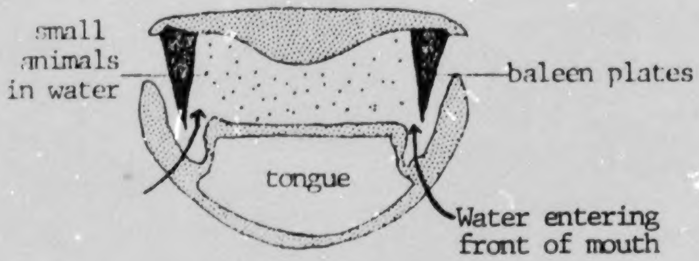
1. The "family tree" below shows how scientists currently view the ancestral history of the whales. According to this view, whales are more closely related to *even-toed ungulates (cattle), odd-toed ungulates (horses), elephants or sirenians (only one of the above is required)* while sea lions are more closely related to bears than to whales.
2. Three characteristics shared by all mammals include: true hair at some life stage, warm-bloodedness, air-breathing, bearing of live young, and nursing of young on mother's milk produced in mammary glands.
3. The primary characteristic used to separate whales and their relatives into two groups is the presence or absence of teeth.
4. a. The smallest toothed whale shown on the chart is the susu.
   b. As an adult (the stage shown on the chart), the susu is less than 10 feet in length (about 6 feet).
5. The average size of sperm whales has decreased because of whaling. If the largest sperm whales now caught are 40 feet long, whalers are killing immature [✓ males]/females and mature male /[✓ females] (Circle the correct words).
6. While this question involves simple mathematics, some of your students may require help in setting up the problem.

$$\frac{60 \text{ tons}}{\text{whale}} \times \frac{.10 \text{ body weight food}}{\text{day}} \times \frac{2000 \text{ pounds}}{\text{ton}} = 12{,}000 \text{ pounds of food/day}$$

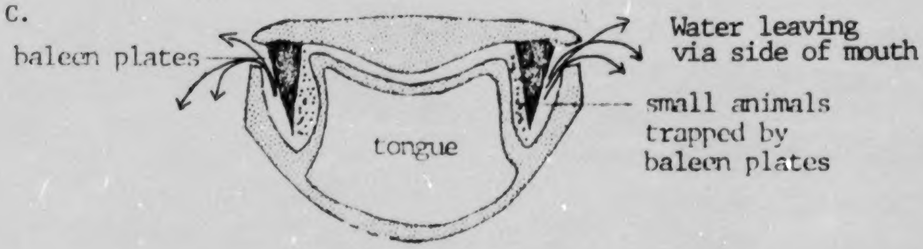
7. Two ways in which a dolphin might use her powers of echolocation to help her survive include: finding food, avoiding collisions, and locating other dolphins.
8. The blue whale is the largest animal that has ever lived on earth, larger than any dinosaur. It can attain a length of over *100* feet and weight of over 130 tons.

9. Correctly labeled pictures should resemble the following:

B.


small animals in water
baleen plates
tongue
Water entering front of mouth

C.

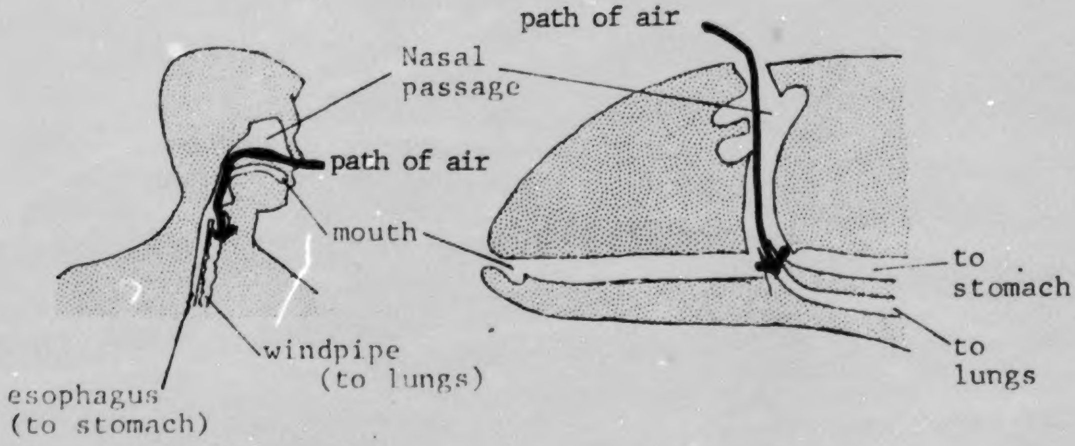

baleen plates
Water leaving via side of mouth
tongue
small animals trapped by baleen plates

10. Again, some of your students may need help in setting up this problem.

$$\frac{\text{6000 pounds krill}}{\text{day}} \times \frac{\text{100 animals}}{\text{pound of krill}} = \text{600,000 animals/day}$$

for one 90 ton adult blue whale.

11.


path of air
Nasal passage
path of air
mouth
to stomach
to lungs
windpipe (to lungs)
esophagus (to stomach)

12. Recorded time will vary.
    a. Your students' breath-holding capacity will be considerably less than that of a sperm whale. This exercise is designed to give your students a feel for the incredible diving ability of sperm whales.
    b. This question emphasizes the point that we breathe automatically when the carbon dioxide level in our blood increases. As a result, you would not have to worry about a child holding her breath until she dies. (You might have to worry about the threat but not about the possibility of asphyxiation.)
13. a. Right whales have a "double spout".
    b. The slanted blow indicates the presence of a sperm whale.
    c. Exhaling beneath the water eliminates the blow and reduces the visibility of the whale. Reduced visibility helps the whale lose its pursuers.
14. Your students will be able to exhale residual air after a regular exhalation. Since whales can almost completely exhale the used air, they retain less air than we do. The whale's lungs would contain little or no "dead" air.
15. While your students may have varied answers, a little discussion should help them arrive at the conclusion that the two body parts most likely to be affected by a lack of oxygen are the brain and the heart.
16. The period of shallow swimming probably provides the whale with an opportunity to recharge the oxygen levels in the blood and muscles.
17. Since dolphins are air breathers, being born tail first reduces the risk of drowning. Although the boby dolphin is still attached at the umbilicus, and is receiving its oxygen from the mother, the danger of the lungs filling with water due to a premature onset of breathing still exists.

KEY

abdomen
adaptations
afterbirth
ancestral
Archaeocetes
baleen
blow
blow hole
carbon dioxide
cetaceans
cetology
characteristic
circulation
class
communicate
crustaceans
crustal plates
dolphin
echolocation
estuaries
evolution
exhale
flipper
fluke
function
herds
invertebrates
krill
mammal
mammary glands
membrane
Mysticeti
nasal passage
Odontoceti
organism
oxygen
placenta
porpoise
primitive
propulsion
relationships
rorquals
social
species
spout
stabilizers
structure
tentative
ultrasonic
umbilical cord
vertical
warm blooded
whale
whalebone

CHILDREN'S WHALE WORKSHOP SOCIETY

P.O. BOX 46529, STATION G
VANCOUVER, B.C., CANADA V6R 4G8
(604) 732 – 7372

RESOURCES: Teaching material, whale information

American Cetacean Society
"The Whalewatcher"
P.O. Box 4416
San Pedro, CA 90731

Defenders of Wildlife
"There's a Sound in the Sea"
A filmscript and teacher's resource
unit on whales.
1244 Nineteenth Street N.W.
Washington, D.C. 20036

Earth Art Works
Steve King
P.O. Box S
Alameda, CA. 94501
phone (415) 769-8500

General Whale
℅ Larry Foster
P.O. Box Save the Whale
Alameda, CA. 94501
phone (415) 865-5550

Greenpeace Foundation
2623 West 4th Ave.
Vancouver, B.C.
phone (604) 736-0321

Colored Whale Chart
"Marine Mammals of the Western Hemisphere"
Superintendent of documents
U.S. Government Printing Office
Washington, D.C. 20402

Stock No. 003-020-00106-8
U.S. Gov't Printing 1975, 653-059

incorporated under the b.c. societies act

WHALE BOOKS, Adults/Advanced

Alaska Geographic. Alaska Whales and Whaling. (Alaska Geographic Society, Vol. 5. No. 4, 1978). Excellent photos and facts on whales.

Brower, Kenneth. Wake of the Whale. $35.00. (E.P. Dutton and Friends of the Earth, 1979). 56 color photos, 46 black and white photos by William Curtsinger. A spectacular book of whales and other marine mammals.

Cousteau, Jacques-Yves. The Whale: Mighty Monarch of the Sea. (Doubleday and Co., Inc., 1972). Good photos and information on whales.

Gatenby, Greg. Whale Sound. (J.J. Douglas Ltd., 1976). Anthology of poems about whales and dolphins .

Griggs, Tamar. There's a Sound in the Sea. (Scrimshaw Press, 1975). A chlid's eye-view of the whale through drawings and poems.

Kellogg, Winthrop N. Porpoises and Sonar. $2.95 paper. (University of Chicago Press, 1961). Research on Porpoises' ability to "see" through their use of sonar.

Kirk, Ruth and Daugherty, Richard. Hunters of the Whale. (William Morrow and Co., 1974). Archaeological dig of a Makah Indian village near Ozette, Washington.

Matthews, Leonard H. The Whale. (Simon and Schuster, 1968). $11.95 hardbound. Folklore and information on whales and whaling. 267 illustrations and photos including ancient woodcuts, whaling maps and prints.

McIntyre, Joan. Mind in the Waters. (Charles Scribners and Sons and Sierra Club, 1974). A book which celebrates the consciousness of whales and dolphins. Poems, photos, graphics, studies and brief encounters with whales.

McNulty, Faith. The Great Whales: Lord of the Fish. (Doubleday and Co., 1974). $4.95 hardbound. Natural history of whales in easy to understand language.

Melville, Herman. Moby Dick. $1.50 paper. (New American Library, 1961 (1851). Epic saga of Captain Ahab, who swears vengeance on a great white whale.

Miller, Tom. The World of the California Grey Whale. $4.00 paper. (Baja Trail Publications, Inc., 1975). Excellent information on grey whales and other marine mammals observable from the west coast, with history, charts, drawings, photos.

Mowat, Farley. A Whale for the Killing. $2.05 paper. (Penguin Books, Inc., 1972). Dramatic account of author's struggle to save a trapped fin whale in Nova Scotia.

Nayman, Jacqueline. Whales, Dolphins and Man. (Hamlyn Publishers, 1973). Biology of whales with many photos.

Nickerson, Roy. Brother Whale. $4.95 paper. (Chronicle Books, 1977). Good introduction to whales focussing on Humpbacks in Hawaii. Photos, and drawings by Larry Foster.

Proctor, Sharon. Whales, Their Story. (Vancouver Public Aquarium, Newsletter, Vol. X1X, No. 4, July-August 1975). Easy to understand brief information on whale biology.

Pryor, Karen. Lads Before the Wind. $8.95 hardbound. (Harper and Row, 1975). Porpoise behavior through research with captive porpoises written in anecdotal and light style.

Scammon, Charles M. The Marine Mammals of the Northwestern Coast of North America. $6.00 paper. (Dover Publications, 1968 (1874). Classic book by a whaling captain and naturalist of the 1850's, numerous drawings by Scammon.

Scheffer, Victor B. The Year of the Whale. $2.45 paper. (Charles Scribners' Sons, 1969). The adventures of a baby sperm whale by a naturalist.

Slijper, E.J. Whales. $2.95 paper. (University of Michigan Press, 1962). Good resource book on whales and dolphins.

Stephen, David. Dolphins, Seals and Other Sea Mammals. (G.P. Putnam's and Sons. 1973). Biology of marine mammals with many photos.

Time-Life. Whales and Other Sea Mammals. $7.95 hardbound. (Time-Life Films, Inc. 1972). Excellent photos of whales, dolphins, manatees, seals, sea lions, walruses, sea otters.

WHALE ARTICLES

Hill, David O. "Vanishing Giants". (Audubon Magazine, Vol. 77, No. 1, January 1975.) Illustrated by Andres Pruna and Richard Ellis.

McVay, Scott. "Can Leviathan Long Endure so Wide a Chase?" (Natural History, January 1971). Assesses extinction of whales.

Payne, Roger. "Swimming with the Right Whales". (National Geographic, October 1972.)

Ibid "At Home with the Right Whales". (National Geographic, Mar. 1976).

Scheffer, Victor. "Exploring the Lives of Whales". (National Geographic, Dec. 1976. Also Graves, William. "The Imperiled Giants".

Walker, Theodore. "The California Grey Whale Comes Back". (National Geographic, March 1971.

WHALE BOOKS, Children

Beaty, John Y. The Baby Whale Sharp Ears. (J.P. Lippincott Co., 1938). Exciting story of the adventures of a baby sperm whale.

Cook, Joseph J. and Wisner, William. Blue Whale, Vanishing Leviathan. (Dodd, Mead and Co., 1973). Blue whale's habits, anatomy and overhunting that led to its near extinction.

Griggs, Tamar. There's a Sound in the Sea. $5.95 paper. (Scrimshaw Press, 1975). A child's view of the whale through drawings and poems.

Grosvenor, Donna. The Blue Whale. (National Geographic Society, 1977.) Story of a baby blue whale. Excellent illustrations by Larry Foster.

Hurd, Edith Thacher. The Mother Whale. (Little Brown and Co., 1973). The birth of a baby whale.

Scheffer, Victor. Little Calf. $5.95 hard. (Charles Scribner's Sons, 1970). Adapted and shortened version of "Year of the Whale".

Steig, William. Amos and Boris. (Farrar, Straus and Giroux, 1971). A moving sroty about a whale and a mouse.

Stonehouse, Bernard. A Closer Look at Whales and Dolphins. (Glouster Press, 1978). Biology of whales for teachers and children. Good resource.

Young, Jim. The Whale Came to My Home Town. $3.95 hard. (Alfred Knopf, 1974). True story of a stranded whale from a child's point of view, simply written, excellent photos.

Zim, Herbert. The Great Whales. (William Morrow and Co., 1951). Facts about whales.

RECORDS

Clayton, Paul. Whaling and Sailing Songs from the Days of Moby Dick. Tradition (TLP 1005). A man descended from a New Bedford Whaling family sings whaling songs.

Collins, Judy. Whales and Nightingales. Elektra (EKS 75o10). One song with humpback whale sounds.

Crumb, George. Voice of the Whale. Columbia (M 3279). Inspired by Humpback Whale sounds, performers use human, electronic and conventional sounds to simulate the sounds of the sea and whales.

Halpern, Ida. Nootka: Indian Music of the Pacific North West Coast. Ethnic Folkways Library (FE 4524).

Horn, Paul. Inside II. Epic (KE 31600). Flute with Killer whale sounds.

Hovhaness, Alan. And God Created Great Whales. Columbia (M 30390). Songs of humpback whales with symphonic orchestration.

Lloyd, A.L. Leviathan! Ballads and Songs of the Whaling Trade. Topic (12 T174). Recollections from shipping on board a whaler, entertaining and informative.

Payne, Roger. Songs of the Humpback Whale. Capitol (ST 620). Actual recordings of humpback whales; beautiful and haunting.

Ibid Deep Voices. Capitol (ST 11598). The second whale record.

FILMS

Beluga Days. 15 min. color. National Film Board of Canada. Distributed by Schoenfeld F-lm Dist., 165 W. 46th Street, New York, NY 10036. 1968. Hunting of beluga whales using Indian methods.

Desert Whales. 22 min., color. Doubleday Multimedia, Box 11607, 1371 Reynolds Ave., Santa Ana, CA. 92705. 1970. Final part of California Grey Whale's southern migration and J. Cousteau's attempt to help a stranded whale.

In Search of the Bowhead. 50 min. color. National Film Board of Canada. 1974. Small expedition looking for Arctic Bowhead whales. Much information. Available through Canadian Consulates or National Film Board of Canada.

Last Days of the Dolphins. 27 min., color. Free loan to schools and organizations. Write "Regional Film Center" nearest you. 915 NW Nineteenth Ave., Portland, OR 97209. Shows tragic killing of thousands of dolphins by tuna fishing industry.

The Sea. 28 min. color. National Film Board of Canada. 1971. Man's relationship to the sea: exploration and overharvesting. Excellent footage.

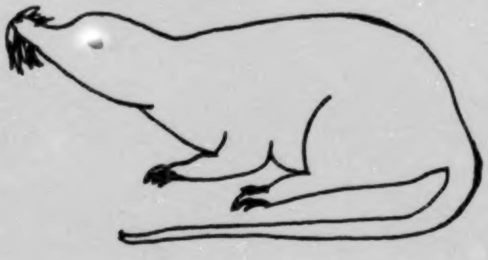
Portrait of a Whale. 12 min. color. National Geographic, 1977. Close-up photography and underwater views of southern right whales.

There's a Sound in the Sea. 11 min. color. Defenders of Wildlife, 1977. Grades 1-4. Colorful and entertaining film of 7 species of whales and the question of whaling.

RETURN TO THE SEA

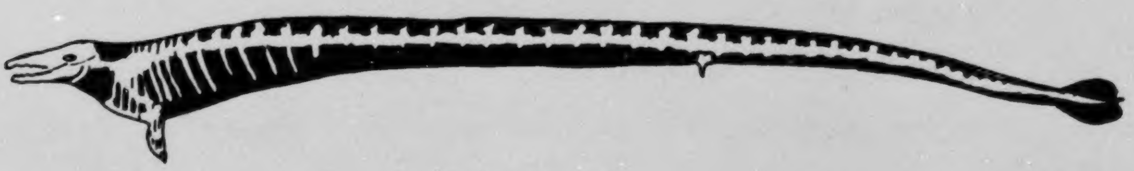
The crustal plates move. The rains fall and the oceans slowly fill. Life begins in the sea. Millions of years pass. The life slowly changes. Animals make the first tentative steps onto the land. Millions of years again pass. The seas and the land are full of animals and plants. Strange fish swim the seas. Vast, swampy estuaries with gently sloping beaches of sand or mud dot the coastlines. A hundred million years ago a small creature wades out into the waters of these shallow seas. We cannot be sure what this creature looked like but we have some ideas.

The small, fur covered mammal had four well-developed legs and a tail. Each leg had a five-fingered foot. The long, thin skull resembled that of a dog and had teeth similar to those of today's meat eaters (carnivores). The stomach was divided into several chambers. This mix of characteristics helped our primitive animal to survive.



"Our Primitive Animal"?

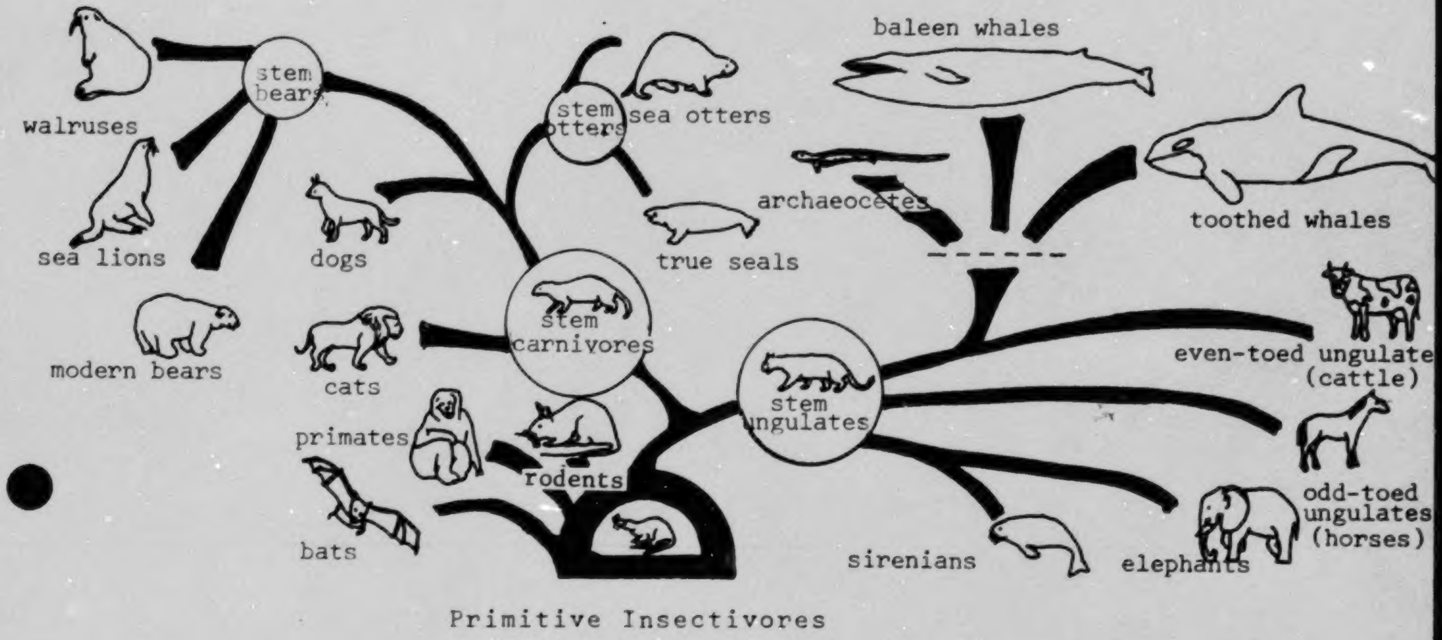
Living on the sloping beaches it may have fed on crustaceans (crabs, shrimp, and their relatives) or small fish. Perhaps it took to wading after them farther and farther out into the shallows. Those individuals that waded further caught more fish and lived to produce young. In time, a grand-child of our animal learned to swim. It could swim after its food more and more quickly. Like a fish, it used its tail for propulsions and its fore-limbs as stabilizers. Millions of years crept past. During this period the five fingers of the fore-limbs became bound together into a flipper. The hind limbs, probably held back motionless against the body and useless for swimming, largely disappeared. The tail widened out to form flukes. Some of our primitive animals swam with whip-like movements of the tail.



Archaeocetes

These animals were successful for a time but soon they were replaced. The replacements swam by means of vertical strokes (up and down) of the tail. The strong, powerful strokes of the tail carried these animals into modern times where man came into their world. Early men huddled on the beach and watched the backs of these animals as they swam. The animals looked like giant wheels revolving in the water. European man called these animals "whales".

1. The "family tree" below shows how scientists currently view the ancestral history of the whales. According to this view whales are more closely related to ______________ while sea lions are more closely related to bears than to whales.


walruses
stem bears
sea lions
modern bears
dogs
cats
primates
bats
stem otters
sea otters
true seals
stem carnivores
rodents
baleen whales
archaeocetes
toothed whales
stem ungulates
even-toed ungulate (cattle)
odd-toed ungulates (horses)
sirenians
elephants
Primitive Insectivores

SUGGESTED MARINE MAMMAL RELATIONSHIPS*

Like their ancestors, modern whales are mammals. This means that scientists put whales into the same class or group of animals to which we belong. Like humans, whales have true hair at some time during their lives. They are warm-blooded. They breathe air. They bear live young (within a special sac called a placenta) and they nurse their young on mother's milk produced in mammary glands. Unlike humans, whales spend their entire lives in the water. They never move onto land.

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*From: "Whales-Their Story." by S.J. Proctor 1975. Vancouver Public Aquarium Newsletter. Vol XIX, No. 4, July-August.

2. What are three characteristics shared by all mammals?

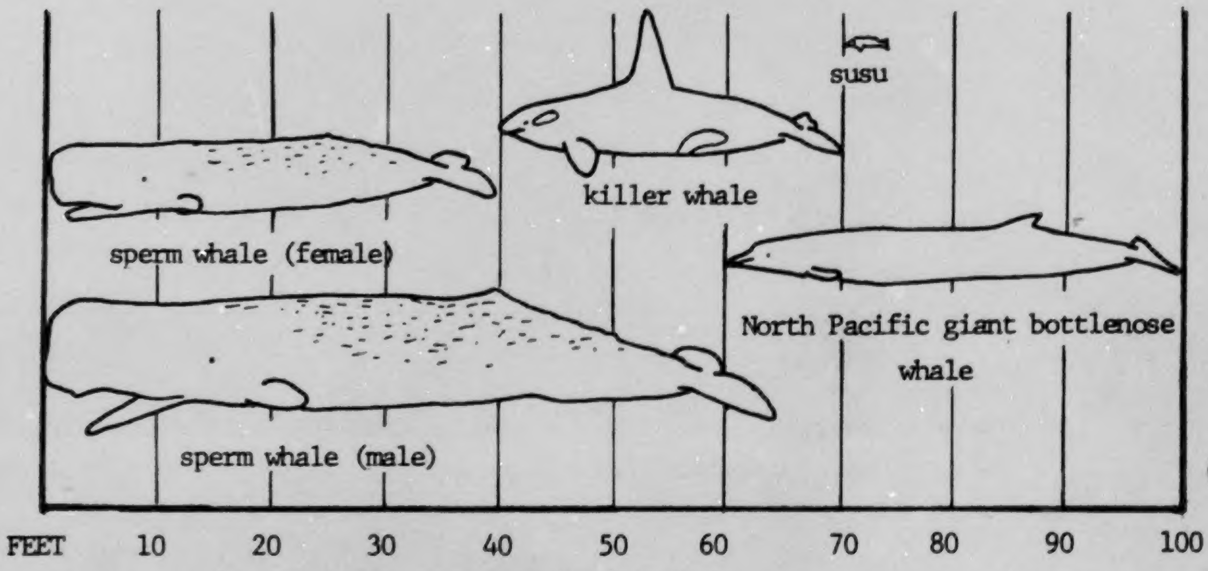
   a)

   b)

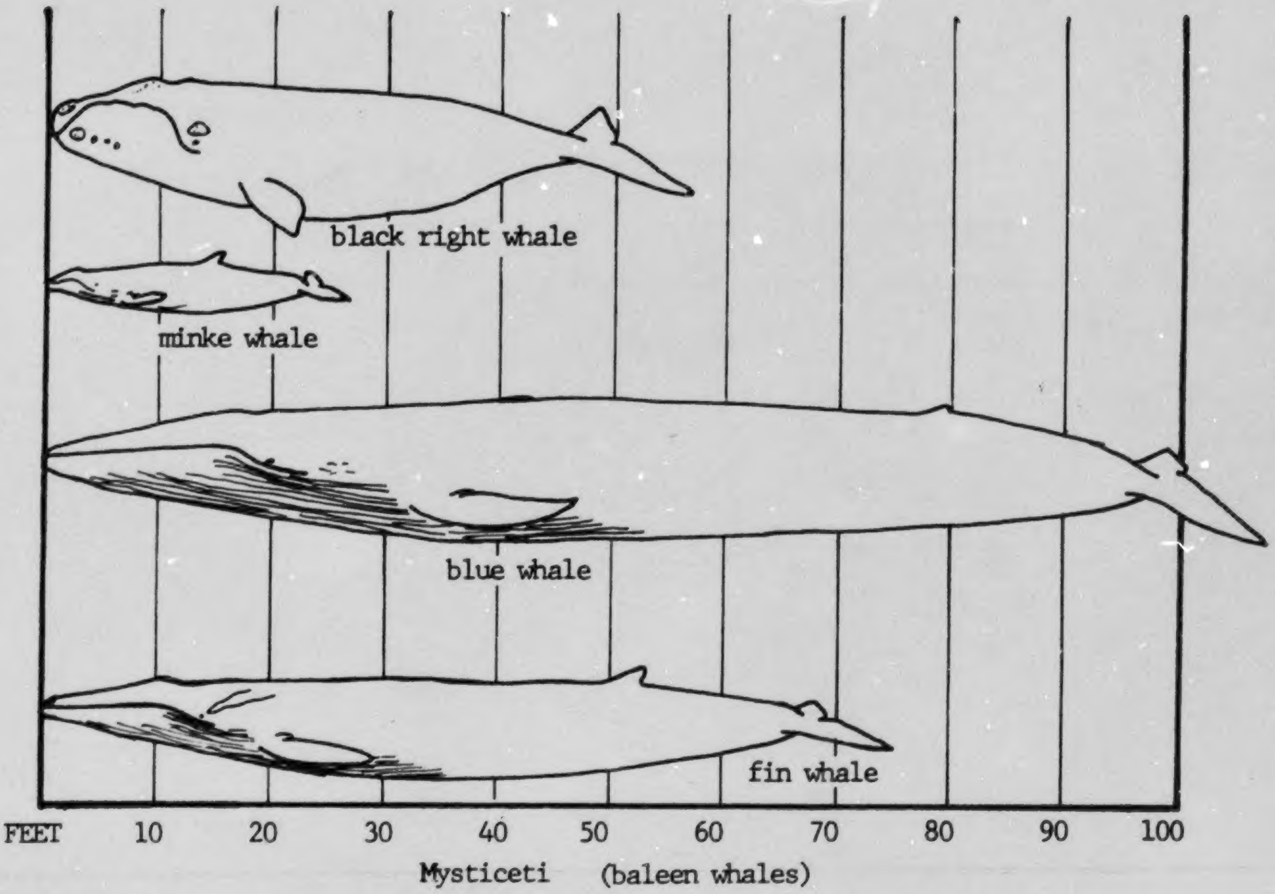
   c)

Types of Whales

Cetology (see-tall-oh-gee) is the study of whales, dolphins and porpoises. (The word comes from the Greek word for whale, cetos). Cetologists divide the whales and their relatives into two groups: those with teeth and those without teeth. Toothed whales belong to the group Odontoceti (Odonto is the greek word for tooth). Whales without teeth belong to the group Mysticeti (Mysti is from the Greek word for moustache).


susu
killer whale
sperm whale (female)
North Pacific giant bottlenose whale
sperm whale (male)
FEET
10
20
30
40
50
60
70
80
90
100

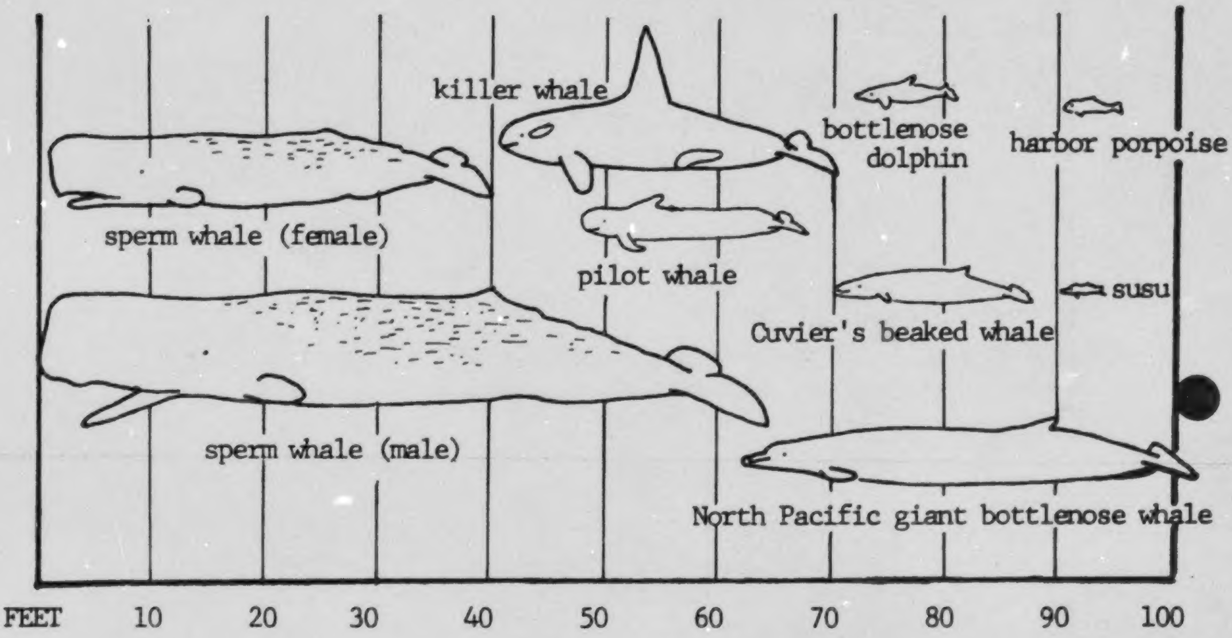
Odontoceti (toothed whales)



3. What primary characteristic is used to separate whales and their relatives into two groups?

The Odontoceti

The Odontoceti is the largest group of whales. All porpoises and dolphins belong to this group. The largest toothed whale is the sperm whale. Sperm whales were made famous as Moby Dick. The chart below shows some of the toothed whales.



ODONTOCETI
(toothed whales)

4. a. What is the smallest toothed whale shown on the chart above?

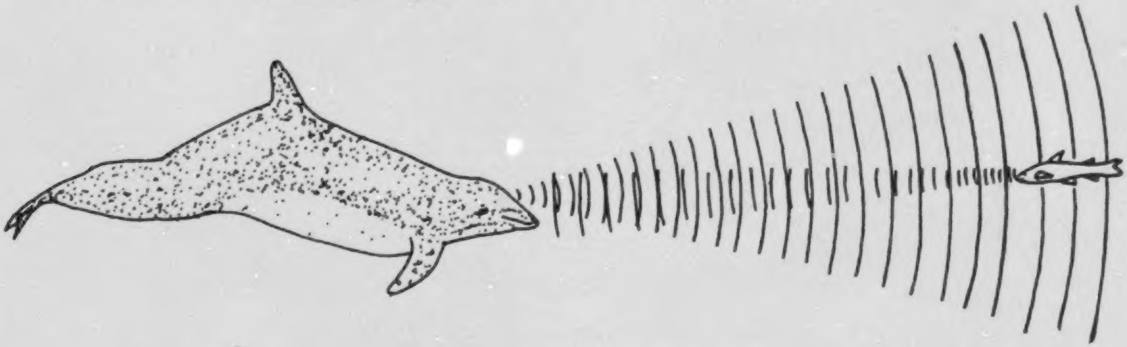
   b. How big is it as an adult?

5. The average size of sperm whales has decreased because of whaling. If the largest sperm whales now caught are 40 feet long, whalers are killing immature males / females and mature males / females. (Circle the correct words)

With a single exception, the toothed whales are carnivorous. This means that they eat fish, squid and other non-plant foods.

6. Toothed whales eat from 5 to 20% of their body weight in food each day. If a 60 ton sperm whale needs 10% of its body weight in food per day, how many pounds of squid and other food must it eat per day? (Hint: 1 ton = 2,000 pounds)

Most members of the Odontoceti spend a least part of their lives in large herds. They keep in contact by sound. These whales have a very good sense of hearing. They can pick up squeaks from within our range of hearing to ultrasonic noises which we cannot hear at all. Like bats, these whales send out sounds and can estimate the position of objects by echolocation.



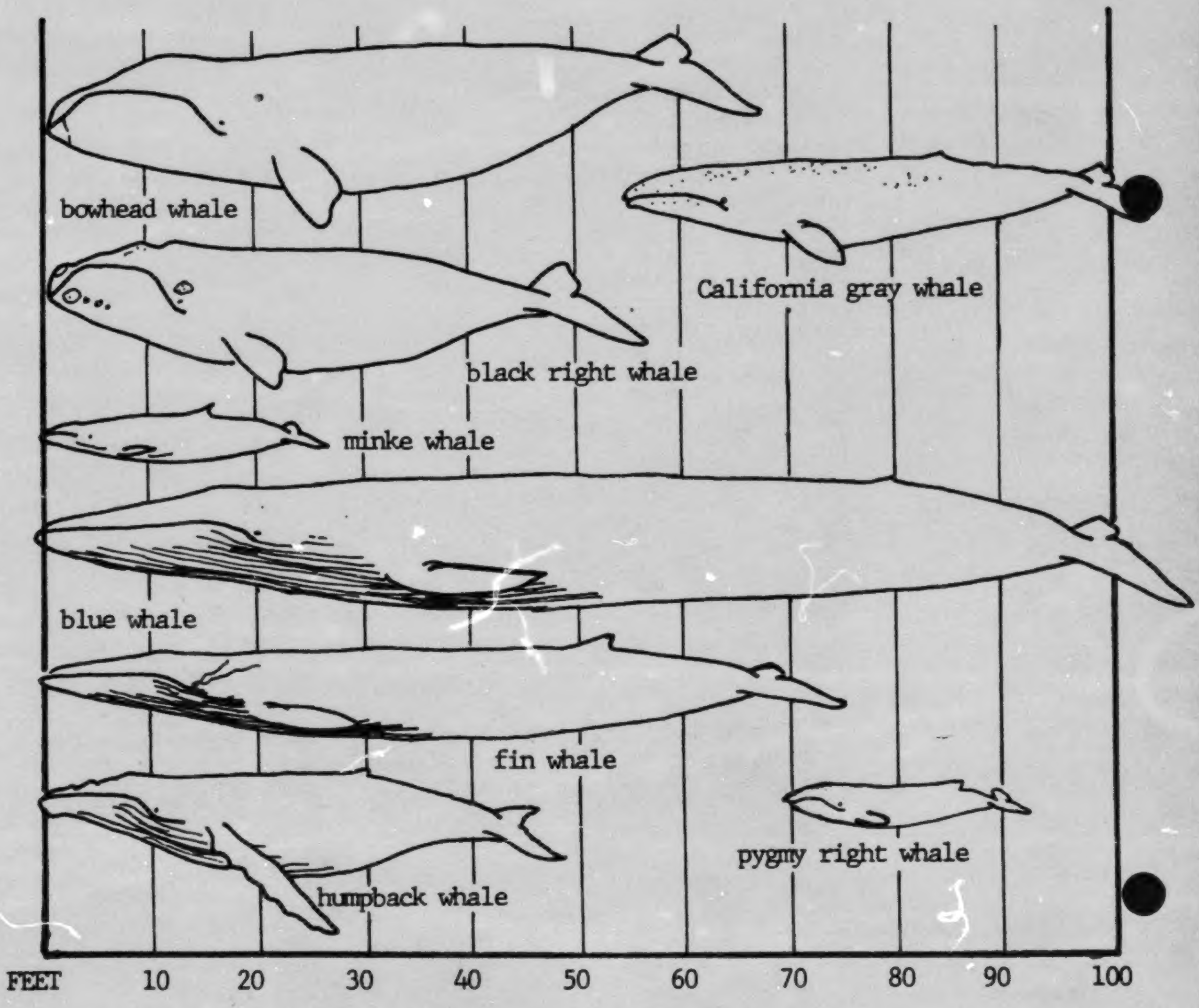
7. The drawing above shows a dolphin echolocating. What are two ways a dolphin might use her powers of echolocation to help her survive?

a)

b)

The Mysticeti

In place of teeth, the Mysticeti have a series of long whalebone plates on either side of the jaw. The whalebone, or baleen, reminded the Greeks of a droopy moustache (mystax in Greek). These moustache-whales use the baleen plates to filter their food from the water. The Mysticeti group includes the giant blue whale, the largest animal of all time. The drawings below show some of the baleen whales.



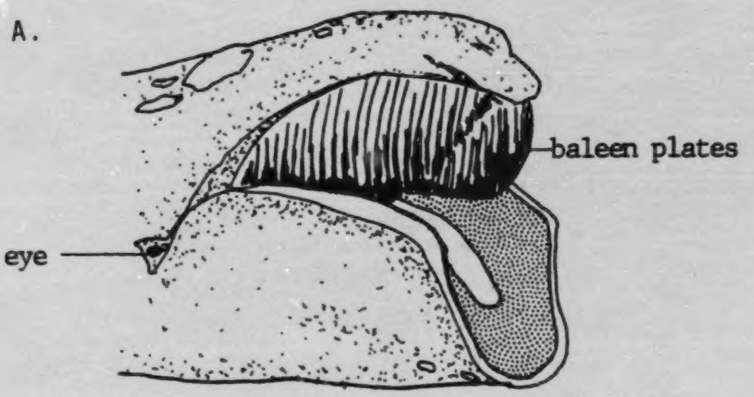
MYSTICETI (baleen whales)

8. The blue whale is the largest animal that has ever lived on earth, larger than any dinosaur. It can attain a length of over __________feet and a weight of over 130 tons.

Other members of the Mysticeti include the right whales, the rorquals, the humpback whale, and the California gray whale. These giant animals feed largely on krill, small shrimp-like crustaceans and their relatives, and small fish.

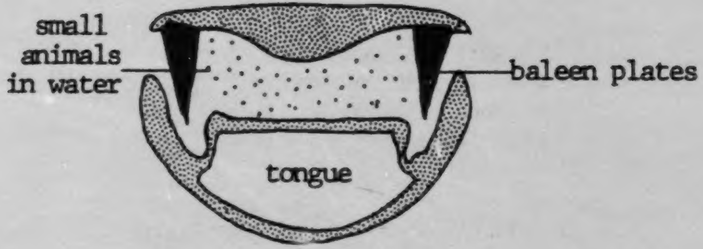
9. How Baleen Whales Feed.

A.



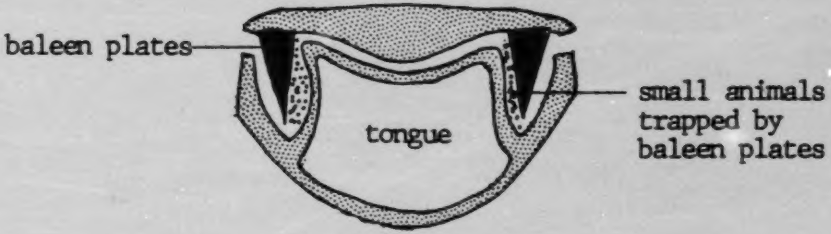
To filter small organisms from the water, the baleen whale has a highly specialized mouth. The baleen plates, made of fingernail-like material, act as a sieve when the animal feeds. The lower portion of the mouth acts like a scoop.

B.


small animals in water
baleen plates
tongue

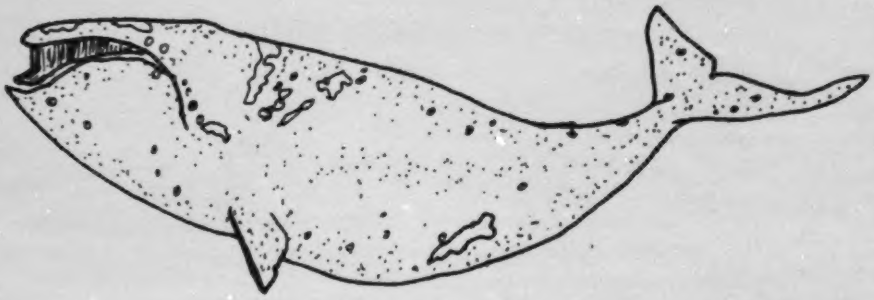
As the whale swims along, it opens its mouth and takes in enormous quantities of water. The water is filled with small organisms (animals & plants). Add arrows to show the flow of water into the mouth.

C.

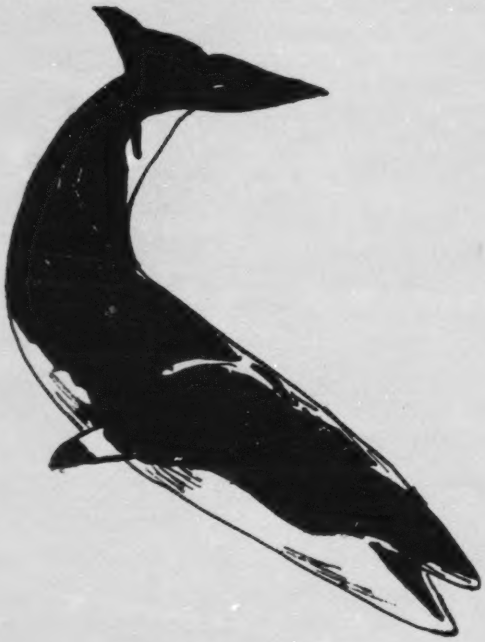

baleen plates
tongue
small animals trapped by baleen plates

The whale then closes its mouth and raises its massive tongue in the center. This forces the water out between the baleen plates. The small organisms are trapped inside the mouth by the plates. Add arrows to show water leaving out the side of the mouth.

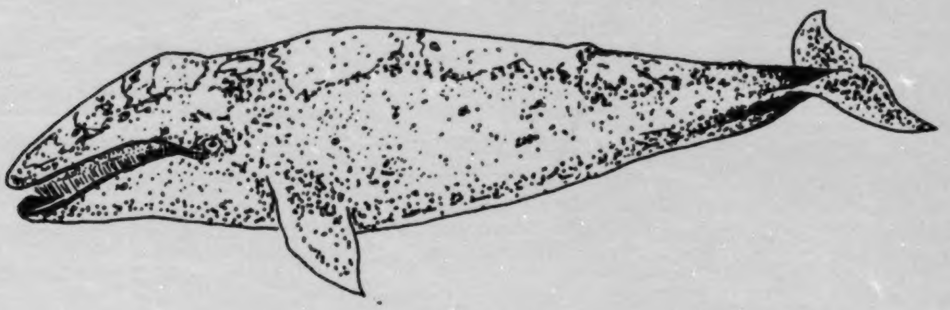
Cetologists place the baleen whales in three groups. The right whales are rounded whales with a high arched upper jaw and long baleen plates.



A second group includes the humpback, the blue whale and the other rorqual whales. Rorqual whales are baleen whales with a distinct back fin.

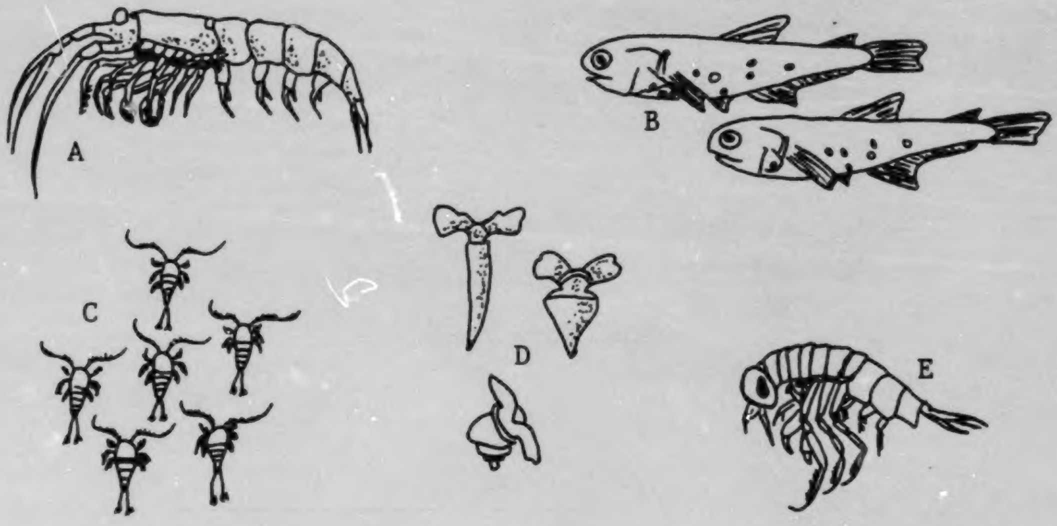


The California gray whale is the only member of the third group. At one time there was an Atlantic gray whale but it is now extinct.



In future activities we will have a chance to learn more about the California gray whale.

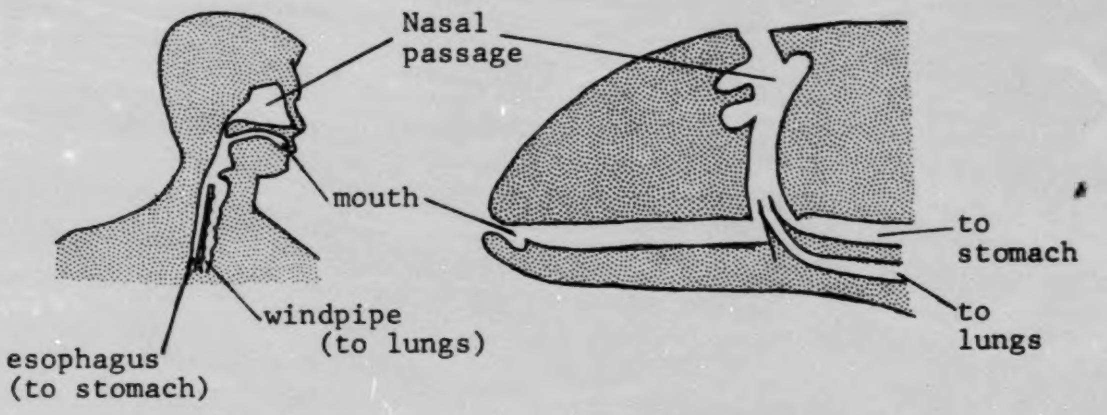
Baleen whales eat many kinds of small creatures that form "schools" in the open sea. These include (A) euphausid shrimps, (B) lantern fishes, (C) copepods, (D) pteropod molluscs and (E) amphipods. Huge concentrations of such creatures in the ocean are termed "krill".



10. A 90 ton adult blue whale eats about 6000 pounds of krill per day. If it takes 100 animals to make a pound of krill, how many krill animals does the blue whale eat per day?

Breathing

Since the ancestors of cetaceans (whales, dolphins and porpoises) were land mammals, they were built to live on land, and to breathe air. Modern cetaceans also breathe air. Their lungs are directly connected to the nasal passage. This arrangement is different from that found in humans. In humans there is a direct conection between the mouth and lungs.



HUMAN CETACEAN (porpoise)

In man the nasal passage opens into the throat. In the throat the nasal passage connects with the mouth, esophagus and windpipe. If we breathe while swallowing, water or food can enter our lungs causing us to cough or choke. In the cetaceans the upper end of the windpipe is extended into a long tube. The long tube fits into the nasal passage. Thus, the animal can swallow and breathe at the same time, with no ill effects.

11. a. Use arrows to show on the drawings the path of the air from the outside to the lungs in man and in the porpoise.

Whales and porpoises can breathe and swallow at the same time. Can you do the same? Try it and see!

We begin to breathe automatically when our carbon dioxide level rises.

12. Obtain a watch with a second hand. Take one (only one) deep breath and hold it. Record the time you can hold your breath.

___________seconds.

While diving, sperm whales can hold their breath for an incredible 90 minutes. Sperm whales and other whales can tolerate (stand) high carbon dioxide concentrations in their blood without triggering a breathing reflex.

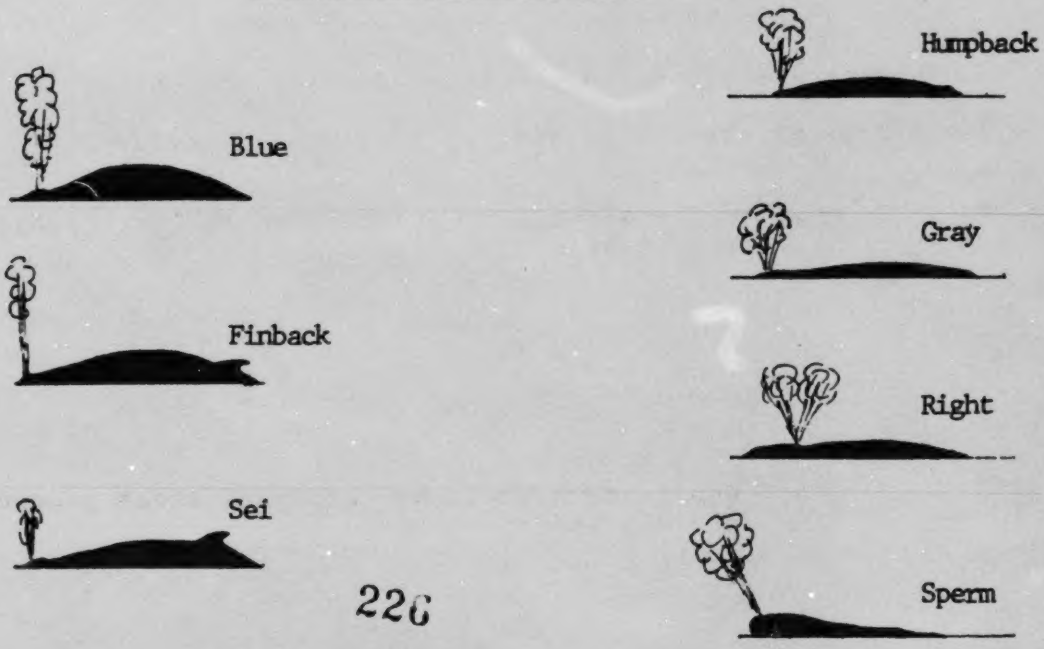
a. How does your breath-holding ability compare with that of a sperm whale?

b. Would you have to be concerned about a young child's threat to "hold

Whale hunters used the whales "spout" to locate the whales. They thought the whale spouted water through their nostrils or blow hole. The "spout" is really the result of warm, moist breath expelled from the lungs, condensing in the cooler atmospheric air. You may have seen something similar when you exhale on a cold, winter morning.

13. Cetologists use the shape and direction of the "spout" or blow to help identify the species (kind) of whale they are observing. Use the drawings of whales surfacing and blowing to answer the following questions.

Surfacing and Blowing Whales *



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* From OSU "Learning About the Ocean" series, "Watching Whales".

a. Which whale has a "double spout"?

b. As observer on the research vessel Margaret R, you see a whale blow. The rather large "spout" is slanted. What kind of whale are you probably viewing?

c. Some whales, when pursued, exhale beneath the water before they surface to breathe. How might this behavior help protect these whales?

Diving

Holding their breath for a long time permits whales to swim to great depths in search of food. Sperm whales have become tangled in underwater phone cables at a depth of 1000 meters (3240 feet). Evolution has drastically changed the structure and function of the cetacean-body. Several of these changes have improved the cetacean diving ability.

Change I. Their lungs use air more efficiently than do ours. They can almost completely exhale the used air and replace it with fresh air.

14. After your next regular exhalation, hold your breath for two seconds then forcefully exhale any additional air you can. Did your lungs retain some "dead" air after your regular exhalation? Would a whale's?

Change II. Cetacean blood holds more oxygen than ours. Cetaceans also have more blood in their bodies than do land mammals of similar size.

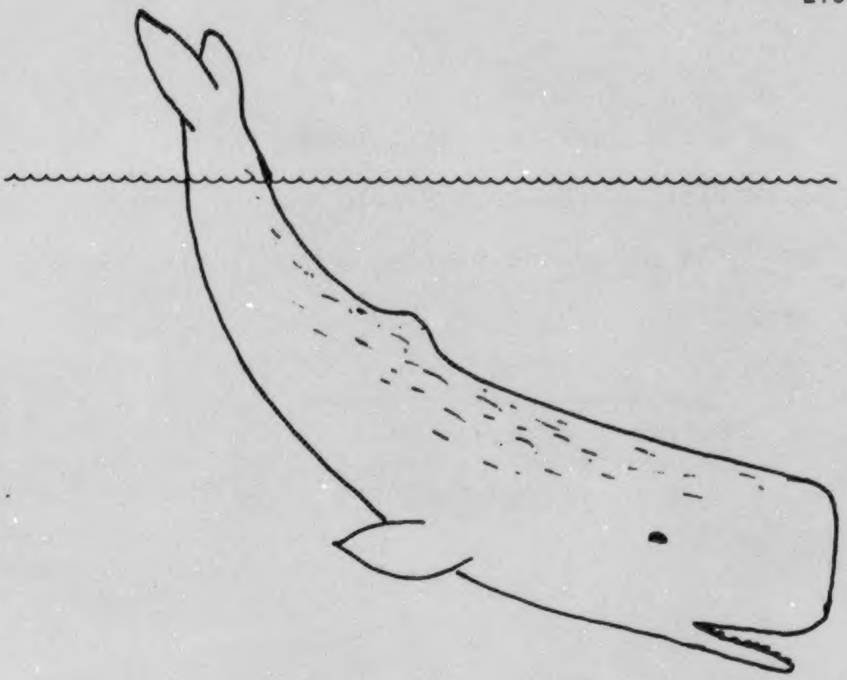
Change III. Their muscles can store a large amount of oxygen for future use.

Change IV. Cetaceans can shut off blood circulation to those parts of the body that can endure lack of oxygen for a period of time.

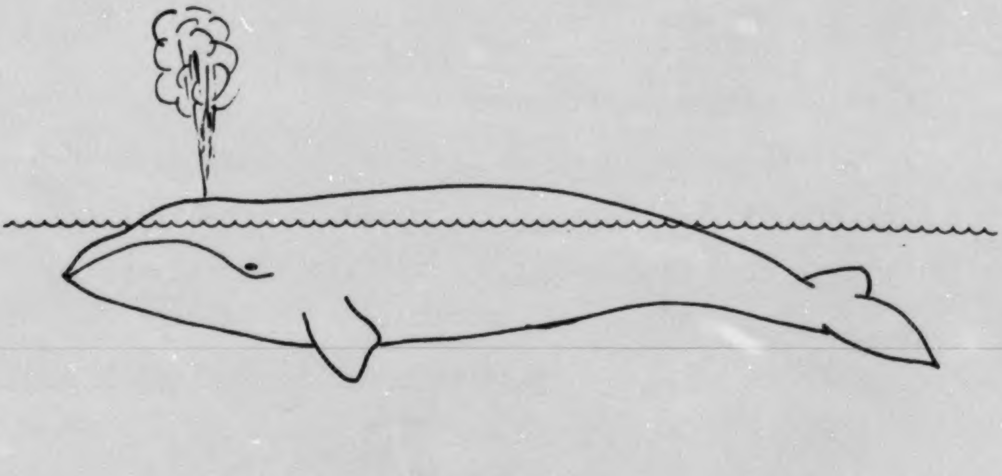
15. Which two body parts are most likely to be affected by a lack of oxygen?

Change V. Cetaceans slow their rate of heartbeat during a dive.

How do these five adaptations turn the cetaceans into super-divers? When a whale, takes several breaths of air at the surface, great quantities of oxygen are taken up by the blood. The blood carries the oxygen to the muscles. Both the muscles and the blood then contain great amounts of oxygen. The whale dives.



The swimming muscles use the oxygen within their own tissues. Most blood circulation in the body is shut off except for that serving the heart and brain. The oxygen in the blood continues to nourish these organs. The slow heart beat conserves energy and prevents overloading of the few organs receiving blood.



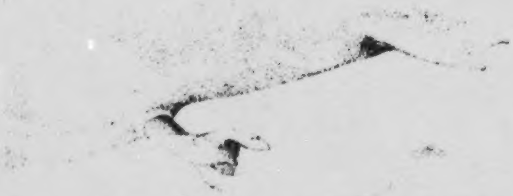
The whale surfaces. The breathing rate increases. The heart rate increases. Excess carbon dioxide is quickly exhaled. The blood and muscles are quickly recharged with oxygen.

16. Surfacing whales generally take several breaths before they again deep dive. What is probably happening to the oxygen levels in the blood and muscles during this period of shallow swimming?

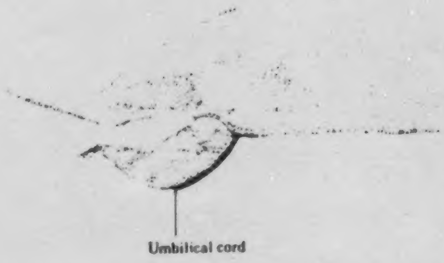
Birth

Cetaceans are born underwater. A female usually gives birth to a single live calf after a development period of between 11 and 16 months. The babies are miniature adults. These calves are about one-third the length of the mother. They are able to swim from birth. Some calves are guided to the surface for their first breath of air. The calves are nursed for up to a year. It is very difficult to study cataceans. Because of this difficulty we still have some questions about the birth process. We answered some of the questions when a baby dolphin was born at the Vancouver Public Aquarium in British Columbia, Canada. The illustrations below show the event.

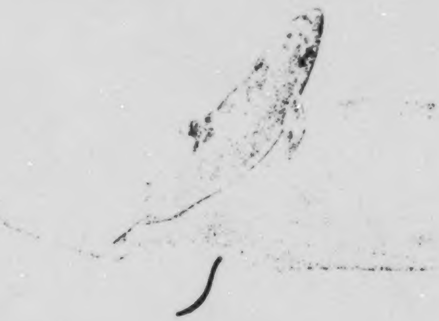
BIRTH OF A DOLPHIN



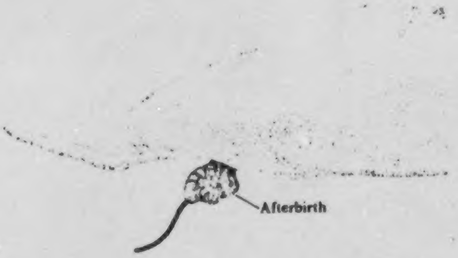
The young dolphin is born underwater tail first. The birth can take from five minutes to two hours.



As the body emerges, tension on the umbilical cord will cause it to break at a weak point, next to the young's abdomen.



Once freed, the baby swims to the surface for its first breath of air. If it fails to do so, the mother can push it upward to the surface.



The afterbirth is expelled from half an hour to several hours later. It consists of the placenta, the rest of the umbilical cord and the fetal membranes.

17. Birth can take from five minutes to two hours. Why might it be an advantage for dolphins to be born tail first?

Overview

Cetaceans are social animals. They depend upon other members of their group. They can survive in a world into which we can venture for only a short time. They communicate with each other by making sounds in the nasal cavity. They have a 100 million year history. They are magnificent. They are threatened.

TEACHER BACKGROUND - How Old?

"Return to the Sea" included a brief introduction to the evolutionary history of the cetaceans. "How Old?" provides additional information about the detective processes of paleontology which have given us our current picture of whale descent. This activity is not intended to be a comprehensive coverage of stratigraphy. It is intended to provide supporting evidence for "Return to the Sea" and to provide a springboard for further explorations in geology. Earth science texts provide a good source for additional information about the topics covered in this section.

In your discussion of this subject refer to the key concepts mentioned in the activity. These include the principle of uniformitarianism which states that the processes (erosion, deposition, etc.) which we observe today have been occurring throughout the history of the earth. A second major concept is the principle of superposition. The principle states that when the layers of rock are horizontal, or nearly so, each overlying bed of rock is younger than the one beneath it. The law of original horizontality follows from this principle. This law states that materials are deposited in horizontal layers. A fourth important concept involves index fossils. Index fossils can tell us the age of the rock formation in which they are found. They can also tell us about the environmental conditions present during the time the rock layer was formed. As an aside, selected index fossils are used by geologists exploring for oil and gas reserves. It is wise to point out that fossils can be transported and redeposited. As such, index fossils are not a fool-proof method of aging rock formations.

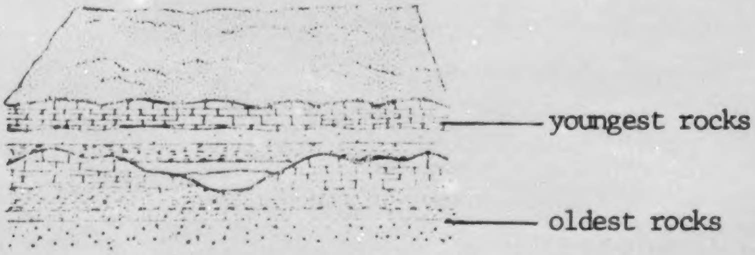
Duplicate the activity pages. One set is recommended per student. This activity is best performed in pairs or groups of 3 or 4. You may wish to introduce this activity by soliciting from your students previous knowledge about the formation of soils and the building of the earth's layers. To help your students visualize the strata, sketch a cross section of a portion of the earth's crust on the blackboard. Limit your strata to three, each indicated by a different color of chalk. This sketch can provide your students with some direction for the construction of their strata-boxes. Clear plastic shoe boxes are available at a nominal cost from variety stores. You have a wide choice of "rock" for the strata.

You may use actual soil types although this tends to be a bit messier than some of the substitutes mentioned in the materials list. Any material that can be layered will work. After the strata are complete (including the index fossil), redistribute the boxes so that each group has a new box. You may elect to redistribute them within a class or between classes. After your students have had an opportunity to complete the activity and the questions, plan to provide time to discuss the procedure and to provide the correct answers. Also plan to provide some time for your students to re-segregate the soil materials. This can be tedious. Judicious selection of your soil materials can facilitate this step.

KEY

Text questions

1. A correctly labeled drawing is found below.



2. The principle of superposition states that when the layers are horizontal, or nearly so, each overlying bed is younger than the one beneath it.
3. The process mentioned in the text that increases the difficulty of age dating the different layers of rocks is the motions of the earth's crust. Vulcanism, a result of this movement, erosion and excavation also increase the difficulty of dating the different layers.
4. This simple math problem is likely to cause your students some intial frustration. If this is the case, provide them with help useful in setting up this (and other similar) problems.

$$1 \text{ centimeter} \times \frac{100 \text{ centimeters}}{\text{meters}} \times \frac{1000 \text{ meters}}{\text{kilometer}} = 100{,}000 \text{ years/kilometer}$$

5. Your students can determine the approximate age of the rock by noting that the uranium has nearly decayed to 50% of its original amount. It is possible to set up the following ratio.

$$\frac{45\%}{55\%} \times 4.5 \text{ billion years} = 3.64 \text{ billion years}$$

This is the best answer your students can give based on the information they have. This answer is only an estimate, however, because radioactive decay is not a straight line function. In reality, during each year that passes, 1/7,700,000,000 of the amount of uranium is changed to lead.

Analysis and Interpretation

1.,2.,3. The answers depend upon the specific design and construction of the individual strata-boxes.

4. The rock layer in which the index fossil is located is about 50 to 60 million years old.

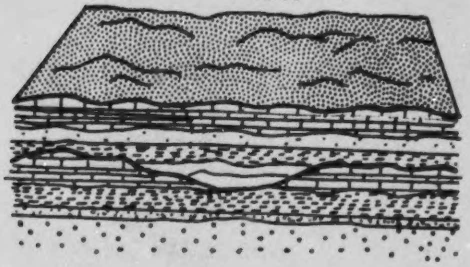
5. a. A reasonable minimum age for the fossil bone is 50 to 60 million years old. This age follows from the fact that the index fossil in the layer above the layer in which the bone was found has an age of from 50 to 60 million years.
   b. A better age estimate for the fossil could be determined from an analysis of the radioactive decay of materials present in the rocks of the layer in which the fossil bone was found.

6. a. Excavation disrupts the rock layers. This question is designed to introduce your students to this idea. The excavation will alter the position of the layers, invalidating the principle of superposition. It may also destroy or move index fossils rendering them of little value.
   b. The losses could be minimized by a pre-excavation examination of the layers or by an excavation sequence that permitted observation of the strata revealed by one phase of the excavation before those strata were completely removed.

7. As mentioned earlier, plan to provide some time for your students to re-segregate the soil materials and clean up the equipment and work area.

KEY WORDS

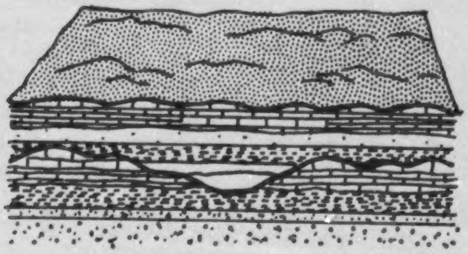
ancestor
atoms
dating
decipher
deposited
erosion
excavation
fossil
grid
horizontal
index fossil
layers
lead
minimized
paleontology
primitive
principle
radioactive
rate
rocks
sediment
strata
superposition
tissues
uranium
vertical



HOW OLD?

What evidence do scientists use to reconstruct the story of the first whales? Most of the information comes from the rocks of the earth itself. Today we can watch the erosion of rocks at the earth's surface. Scientists believe that the processes of erosion that we observe today, have been occurring throughout the history of the earth. Over the years, these erosive forces have built up layers, or strata, of rocks. These rock layers give us a clue to the past.

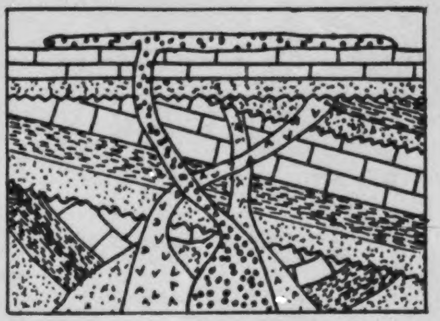
The most basic principle used in understanding the record of these rock strata is a simple one. When the layers are horizontal, or nearly so, each overlying bed is younger than the one beneath it. This is called the principle of superposition.



1. On the drawing above, label the oldest and youngest rock layers (strata).

2. What is the principle of superposition?

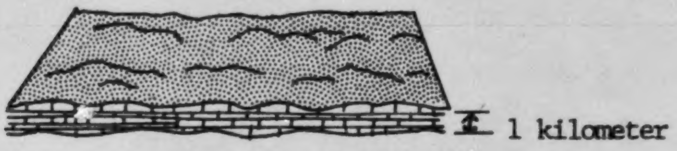
Because the earth's crust is in motion, it is not always as easy as it might sound to tell the age of the different layers. The diagram below shows a cross-section of a piece of the earth's crust. Crustal motion makes this section of earth difficult to "read." Geologists have devised methods to decipher ("read") these confusing rock records.



3. What is one process that increases the difficulty of aging the different layers of rocks?

The position of the layers of rock tells us which rocks are oldest. It does not tell us how old the rocks are in terms of years. Geologists can make reasonable guesses of the age of rocks by noting the rate of deposition. For example, if we can determine the rate at which a sediment layer is deposited, we can determine the age of the layer.

4. The diagram below shows a series of rock layers. The labeled section is 1 kilometer deep. It was deposited at a rate of 1 centimeter per year. How old is the bottom layer?



(Hint: This is easy, if you remember that
1 kilometer = 1000 meters and
1 meter = 100 centimeters,
then all you need to find out is the number of centimeters in a kilometer)

These methods gave early geologists an idea of the age of certain rock layers. The last half century has provided scientists with several powerful new tools to date rocks. We know that certain kinds of radioactive atoms are unstable. These unstable atoms change from one form to another over time. We know the rate at which the change (called radioactive decay) takes place. For any rock, we can measure how many atoms have changed and how many have not. From this information we can determine the age of the rock in which these materials are found.

5. Uranium 238 changes to Lead 206 by radioactive decay. It takes 4,500,000,000 (4.5 billion) years for half (50%) of the uranium in a given rock to change to lead. The rock you are studying contains 45% lead and 55% uranium.

So now we have an idea of what the layers of rocks tell us and how old each layer is. How does this information relate to our history of the whale?

Primitive animals had a least one thing in common with modern animals. They died. At death, "our primitive animal" settled into the soft mud and sands of the coast zone where it lived. The soft tissues disappeared. The skeletal materials were replaced by harder minerals. The skeleton was transformed into rock, a specialized rock called a fossil. Fossils are naturally preserved remains of animals and plants. Certain fossils are called index fossils. Index fossils are useful to geologists because they are found in rock layers of only one geologic age. They serve to identify specific rock layers no matter where they are found.

From the fossil record we can reconstruct our primitive whales. In the following activity you will have a chance to sharpen your geological and paleontological (fossil studying) skills.

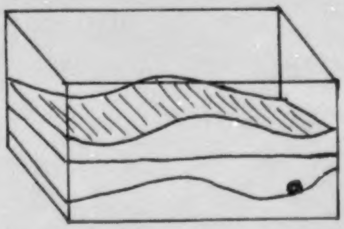
Materials:

- clear plastic shoe box
- sand, gravel soil, pea gravel, dried beans, dried peas, macaroni, stryrofoam packaging, etc. (any 3)
- index fossil (glass marble)
- centimeter rulers (2)
- centimeter grid paper
- plastic sandwich bags
- masking tape

Procedure:

PART A - Strata-box

1. Obtain a plastic shoe box, an index fossil and samples of three different types of "rock".
2. Using a little imagination, lay down rock strata, one on top of another. Remember that strata are not always level. Choose a layer that looks interesting to you. Place your index fossil in that layer and next to the side. Your index fossil should be visible through the strata-box. Your strata box might look something like this.

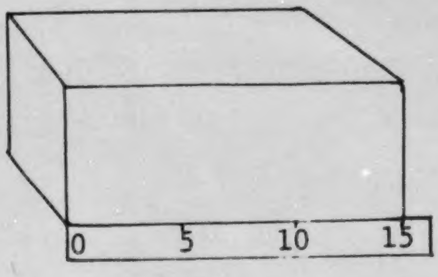


3. Place a small piece of masking tape on the top right hand corner of one of the ends of the box. Write your name and period on the tape.
4. Following the directions of your instructor, exchange boxes.

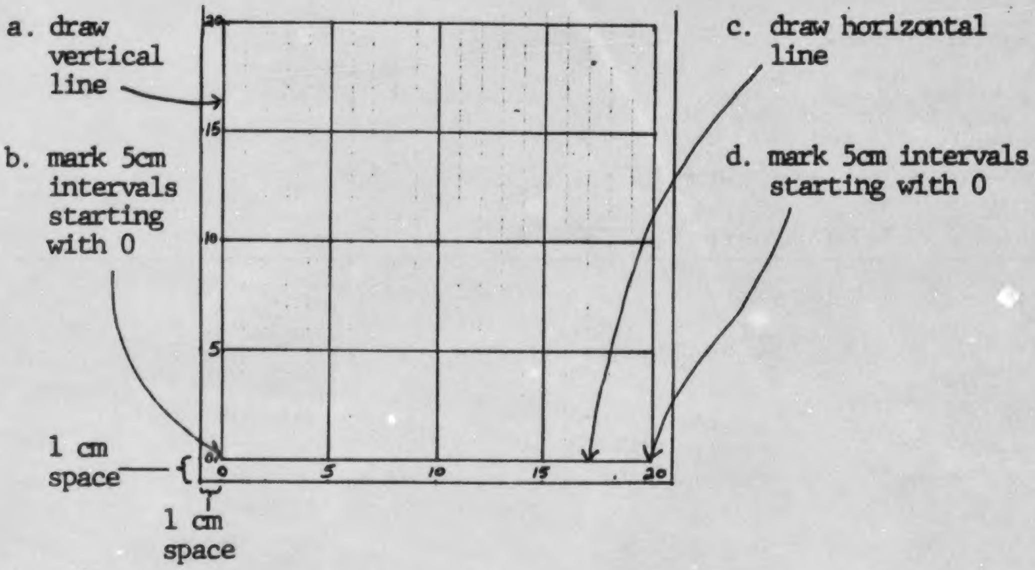
PART B - The Hunt Is On

1. Obtain a piece of centimeter grid paper and two centimeter rulers.
2. Tape one of the centimeter rulers to your desk top with a small piece of masking tape.

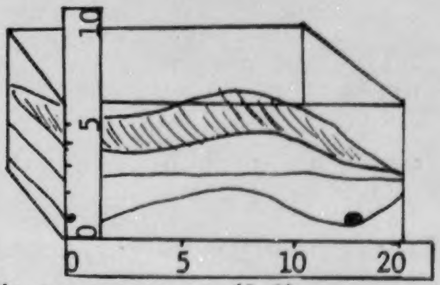
3. Place the strata-box from your teacher on your desk top so that the corner of the box lines up with the 0 of the centimeter rule taped to your desk top. Be sure your index fossil faces forward. Your arrangement should look something like this.



4. Mark your 1 cm grid paper in the following way:

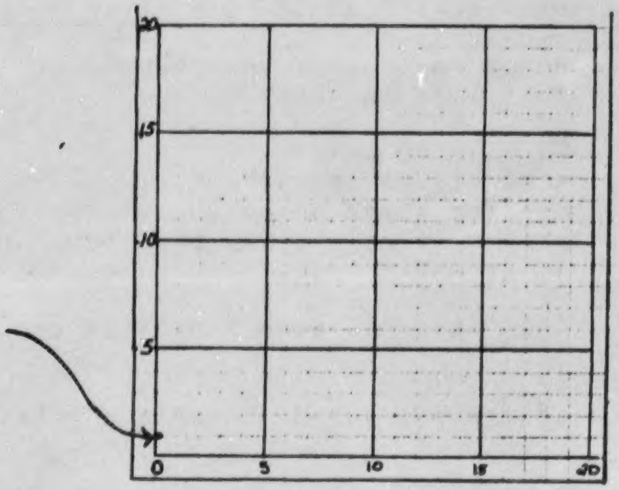

a. draw vertical line
b. mark 5cm intervals starting with 0
c. draw horizontal line
d. mark 5cm intervals starting with 0
1 cm space
1 cm space
0
5
10
15
20
0
5
10
15
20

5. Use your other ruler to measure the depth of the three strata. Measure one strata at a time. Hold the centimeter ruler vertically above the 0 point on the ruler taped to your desk. Your arrangements should look something like this.



First measure at (0,0)

Measure the height of the lowest strata at the point above 0. Mark this point on your grid paper. The correct mark for the strata-box shown above would be:



Mark this point

6. Repeat step 5 at 5 centimeter intervals across the bottom strata.

7. Repeat steps 5 and 6 for the other two strata.

8. Connect the points for each strata.

Analysis and Interpretation

1. What material makes up each of your strata? Label each strata on your grid paper.

2. On your grid paper, sketch in the position of the index fossil.

3. From oldest to youngest, list your three strata types.

   a.

   b.

   c.

4. Index fossils are useful to geologists because they are found in rock layers of only one geologic age. They serve to identify specific rock layers no matter where they are found. The index fossil you have found lived during a period 50 to 60 million years ago.

   a. About how old is the rock layer in which your index fossil is located?

5. Being as clever as you are, you have noticed a rounded rock in the layer below your index fossil. Careful excavation reveals a jaw bone from an Archeocetes, a primitive whale ancestor.

   a. What is a reasonable minimum age for your fossil bone?

   b. What might you do to obtain a better age estimate?

6. Developers are planning a shopping center for your strata-box.

   a. What kind of information about the age of the layers may be lost during the excavation for the center?

   b. How could these losses be minimized?

7. Following your teacher's directions dismantle the strata boxes.

TEACHER BACKGROUND - Putting All The Pieces Together

"Putting All The Pieces Together" gives your students a chance to reconstruct whale skeletons from pieces thereof. Ideally, you would provide your students with a disarticulated skeleton or skeletons to reconstruct. Practically, this is seldom possible. The two dimensional "skeleton sets" provided in this activity are a reasonable substitution. The reassembly of the skeleton sets is much simpler than the reconstruction of a fossil skeleton. Nonetheless, some of the same detective and observational skills are required. The activity is designed to give your students a small taste of the work of paleontologists. Hopefully, this activity and your support will encourage them to explore the field more fully on their own.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished by individual students as an in-class assignment. It is possible to have your students do the skeleton assembly at home although the logistics of transporting the taped skeletons present some problems. In Part A, the skeletons are complete with the exception of a few vertebrae. An additional skull has been included to add to the excitement. In Part B, all of the flipper bones are present. No additional bones are included. If you wish to make the activity in Part A more challenging, you can do so by reducing the size of the pieces through judicious use of your scissors. Make a paste-up of the new pieces for duplication. To facilitate the comparisons your students are asked to make, have your students display their completed skeletons on a class-room bulletin board. The skeletons can also serve as interest generators for other classes using the room. Provide ample waste bastets for the cutting scraps. Allow some time for a discussion of the questions posed in the "Analysis and Interpretation" sections.

KEY

Completed skeletons are found at the end of the Teacher Background section.

Analysis and Interpretation - Part A

1. a.b. While the answers depend upon the individual outcomes, most of your students will construct three complete skeletons and one incomplete skeleton (skull only).
2. a. There are many things that might cause part of a skeleton to be missing. Predation on the animal after death might have scattered the bones. Only part of the skeleton may have been fossilized. Part of the fossel skeleton may have been carried away when the rock beds in which it was found were eroded. More recent differential excavation may have caused part of the skeleton to disappear.

   b. Two or more skeletons are commonly found in a single site. There are several possible reasons for this: (1) The site may have been frequented by many animals during some past era (e.g. a watering hole). (2) The site may have been particularly well-suited to the formation of fossils from deceased animals (e.g. some of the warm, shallow seas). (3) The site may have had a unique combination of features that favored fossil formation (e.g. The La Brea tar pits). Your students may have some other, more original, ideas.
3. It is more difficult to assemble a skeleton from completely disarticulated bones because the number of possible combinations increases tremendously. The partially completed skeletons also provide some clues which help direct assembly. The clues are missing in the complete disarticulated skeleton.
4. The answer depends upon the experimental results. Most of your students will find that the longest skeleton was about 45 cm long.
5. a. While the answer depends upon the class results, it is doubtful that all of the skeletons are exactly the same.

   b. The differences among the skeletons come from differences in interpretation and observation.

6. Paleontologists use information from other fossil associations to determine which reconstruction is most accurate. A comparison of skeletons and parts of skeletons from different sites increases the accuracy of reconstruction. Some fossils also conveniently deposit themselves in a near perfect skeleton. In these cases, the manner in which the fossil is excavated can establish a great deal about the actual articulation of the bones.

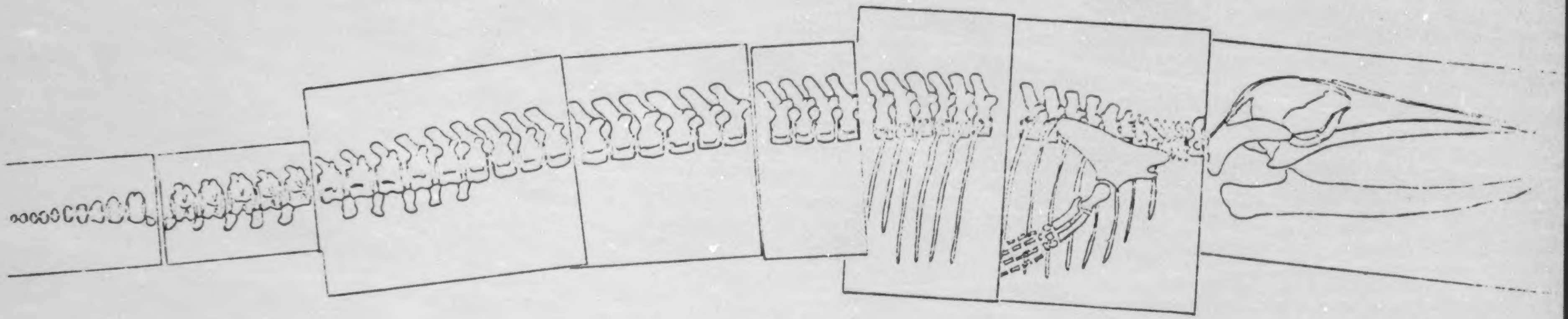
Analysis and Interpretation - Part B

1. If the bones are correctly assembled, the completed body part should appear to be a hand, foot or flipper. The skeleton part is actually a bottlenose dolphin flipper.
2. a. While the answers will vary, most of your students will find it difficult to assemble the flipper in Part B.
   b. The flipper is more difficult to reassemble because it is totally disarticulated. There are few reference points. Your students are also likely to have fewer preconceived notions about the expected results.
3. a. While the answer depends upon the class results, it is doubtful that all of the skeletons are exactly the same.
   b. Again, the differences among the skeletons come from differences in interpretation and observation.
4. After experiencing some of the difficulties inherent in reconstructing skeletons, your students should more readily accept the fact that differences in the interpretation and observation of the fossil bones could account for one person making a 114 foot long skeleton and another person making two 55 foot long skeletons out of the same bones. In all fairness to paleontologists, it should be mentioned that Dr. Koch had somewhat questionable credentials and was looking for a bit of sensationalism and fortune (both of which he found). He exhibited his mounted skeleton in New York and Europe and caused quite a sensation both here and abroad.

KEY WORDS

excavation
flipper
fore-limb
paleontologist
porpoise
reconstruct
reconstruction
serpent
site
skeleton
skull
structure
vertebrae

WHALE SKELETON



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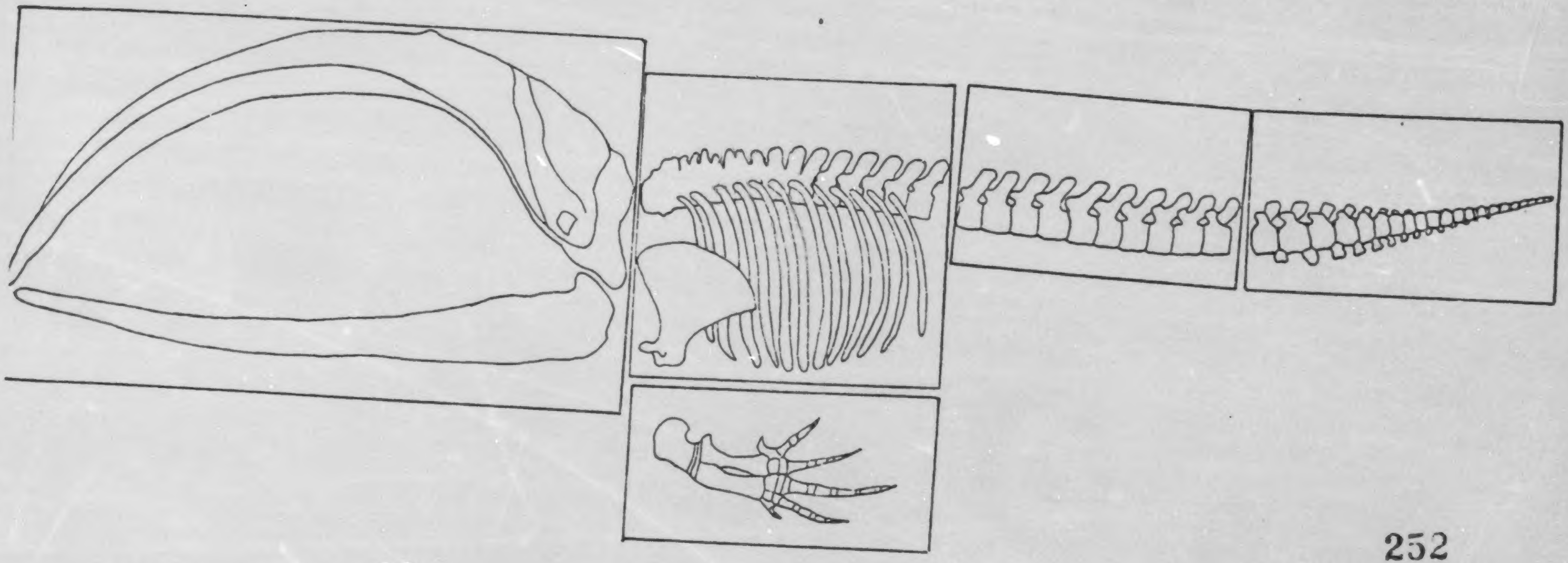
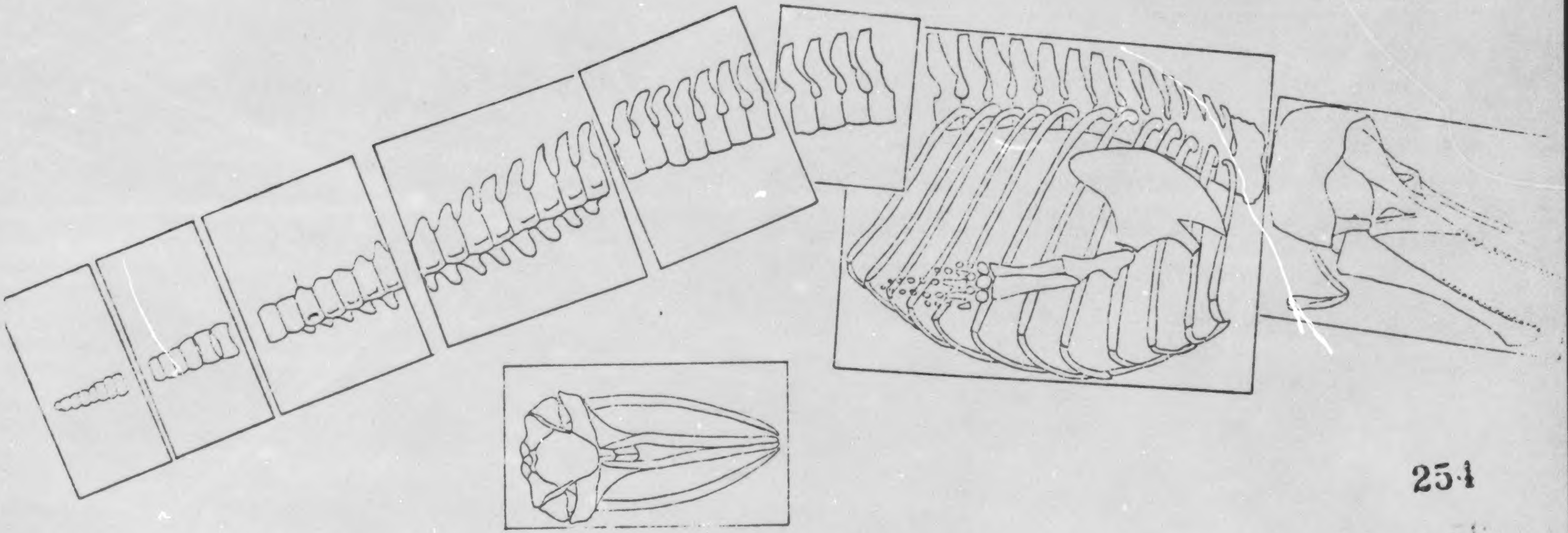
250

WHALE SKELETON



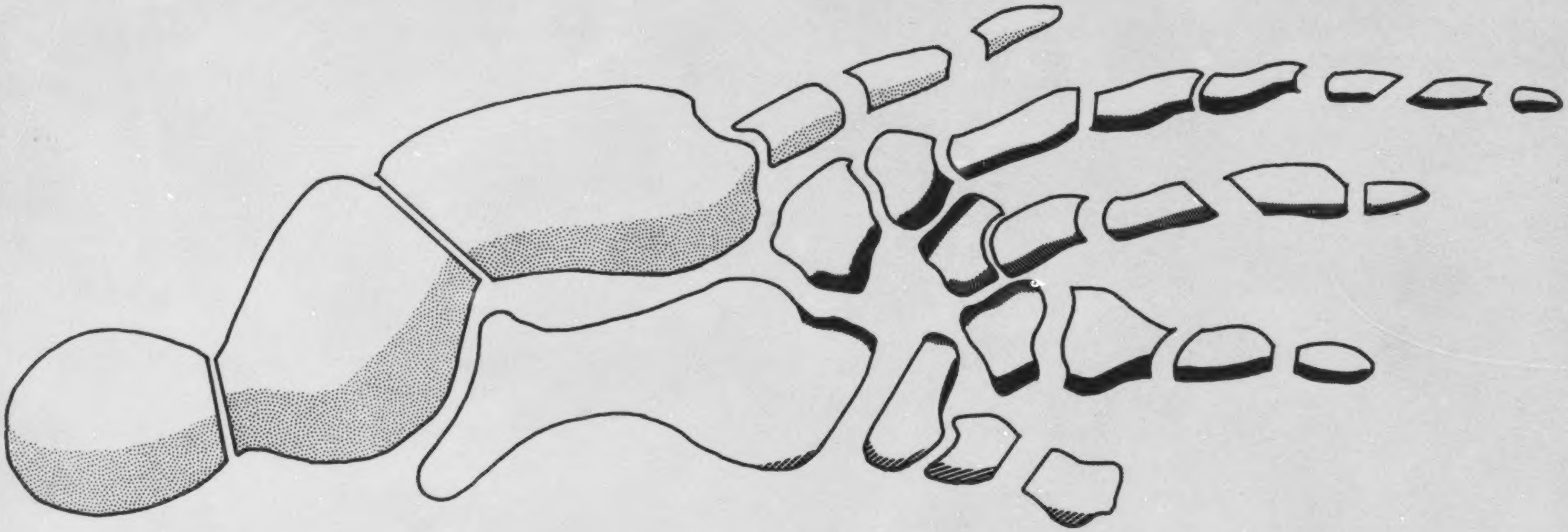
WHALE SKELETON



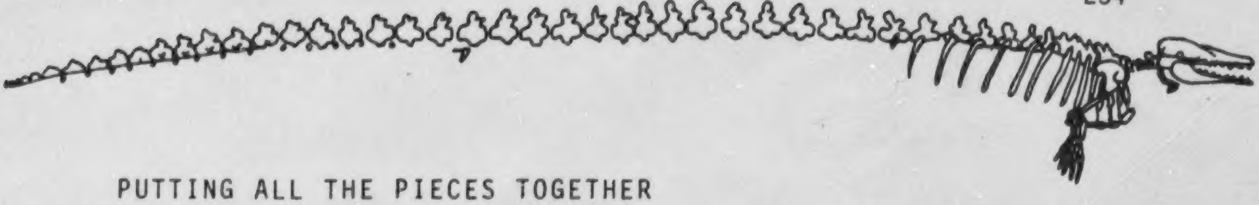
(extra skull)

253

254



BOTTLENOSE DOLPHIN FLIPPER



PUTTING ALL THE PIECES TOGETHER

In 1845 a certain Dr. Albert Koch dug up some enormous vertebrae. He then added some others and a skull. He mounted these bones into a skeleton which he exhibited as the first sea serpent. He called the 114 foot long animal Hydrarchos, the water chief. The scientist, Richard Owen, pointed out that the skeleton was really made up of two separate animals. The skeleton in fact, the remains of an early whale. As he reconstructed it the creature was still 55 feet long. It had a long snake-like tail. The tail probably helped it swim quickly with a whip-like action. It was a snake-shaped animal with a dog-shaped skull. The fore-limb was a flipper with five fingers in the hand and with an elbow. There were traces of a thigh bone.

Since the discovery of these early serpent-shaped whales many other remains have been found. Skeletons have been discovered in various parts of the world. They have been especially numerous in Egypt and on the Gulf Coast of the U.S.A. Some of them were shaped like sea serpents. Others were like modern porpoises. How do paleontologists reconstruct fossil animals? How could one person make a 114 foot long skeleton and another person make two 55 foot long skeletons out of the same bones? In the following activity you will have a chance to answer these and other questions as you "put all the pieces together".

Materials:

- skeleton set
- scissors
- centimeter ruler
- transparent tape
- bone set

Procedure:

PART A

1. Obtain a skeleton set, scissors and a centimeter ruler.
2. Use your scissors to cut out the skeleton pieces.
3. Spread out the skeleton pieces on your desk top. Use whatever clues you can to fit the pieces together into one or more animals or parts of animals. Some bones may be missing, some may be extra.
4. After you are satisfied with your skeleton(s), tape the pieces together.
5. Use your reconstructed skeleton(s) to answer the questions that follow.

Analysis and Interpretation:

1. a. How many complete skeletons did you construct?

   b. Did you have any incomplete skeletons?

2. a. In the real world, what might cause part of a skeleton to be missing from an excavation site?

b. What might account for two or more skeletons being found in the same site?

3. The skeleton pieces you "dug up" were made of several bones. If you were given a set of individual bones, would it be easier or more difficult to assemble the skeletons? Why?

4. How long is your animal? If you reconstructed more than one animal, how long is the longest animal?

5. Put your name on the skeleton(s). Compare your skeleton(s) with those of others in your class.

   a. Are all of the skeletons exactly the same?

   b. If not, how can you account for the differences?

6. What additional information would paleontologists use to determine which of the skeleton reconstructions is most accurate?

PART B

So now you're an old hand at skeleton reconstruction. The following exercise is a bit more challenging.

Procedure:

1. Obtain a bone set.
2. Use your scissors to cut out the various bones.
3. Spread out the "bones" on your desk top. Use whatever clues you can to fit the pieces together into a body part. (Hint: all of the bones fit together to form one structure)
4. After you are satisfied with your creation, tape the bones together.
5. Use your reconstruction to answer the questions that follow.

Analysis and Interpretation:

1. What does your completed body part appear to be?
2. a. Was it more or less difficult for you to assemble this part of a skeleton than the whole skeletons in Part A?

   b. If it was more difficult, what made it so?
3. Put your name on your reconstruction. Compare it with those of others in your class.

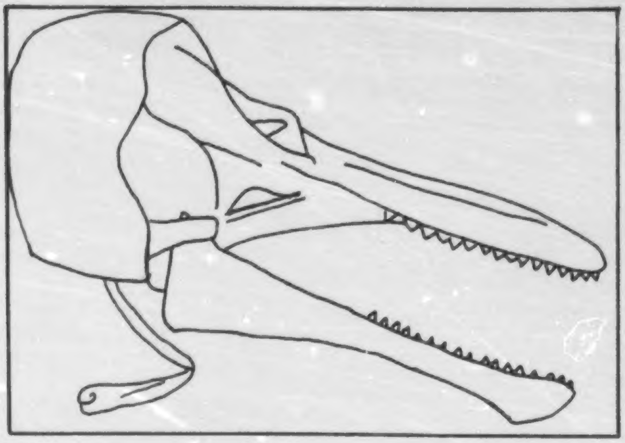
   a. Are all of the skeletons exactly the same?

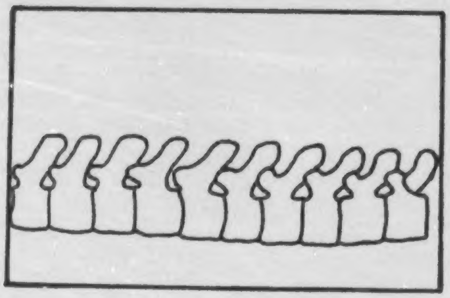
   b. If not, how can you account for the differences?

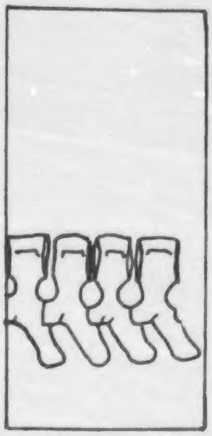
4. Now you can answer our original question. How could one person make a 114 foot long skeleton and another person make two 55 foot long skeletons out of the same bones?

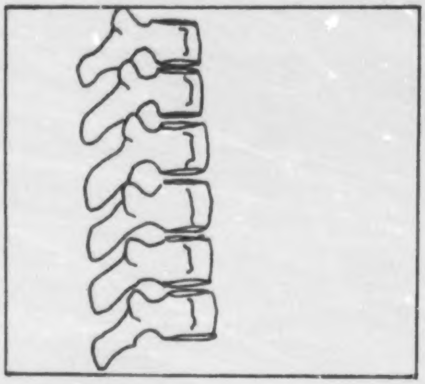
SKELETON SET

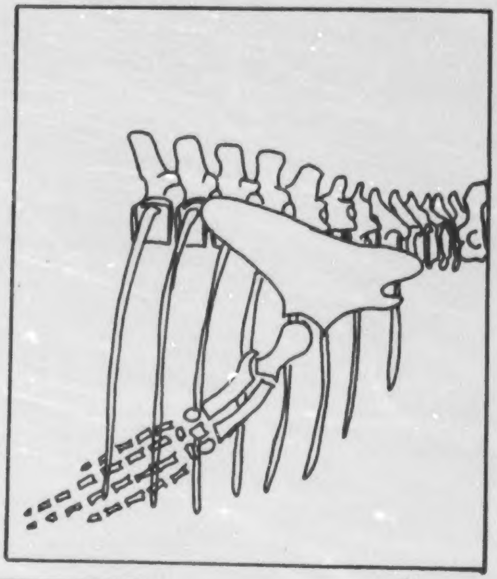
PART A

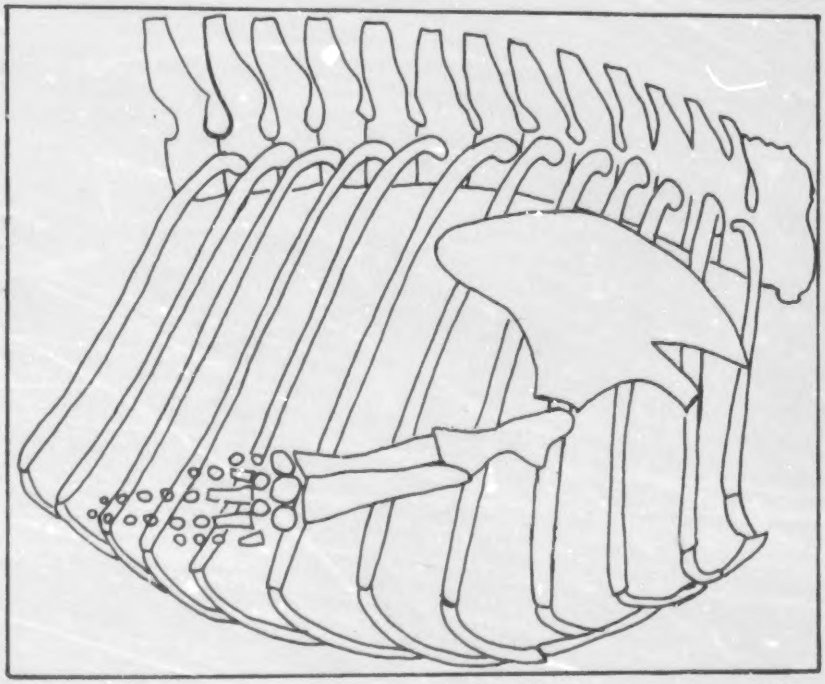


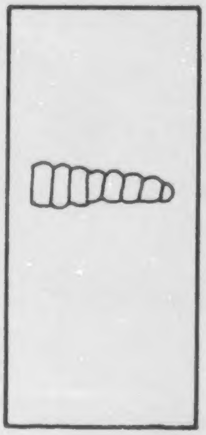






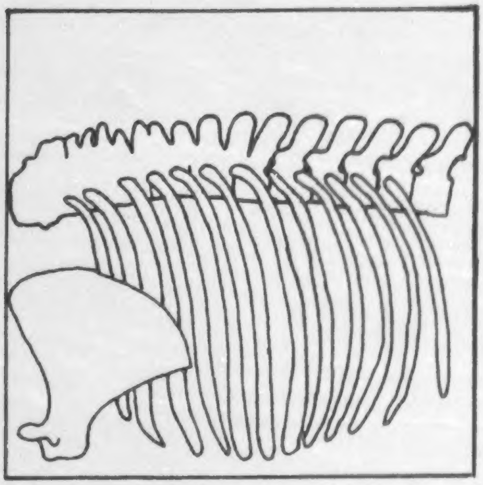


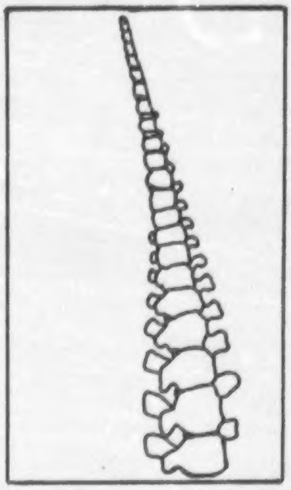


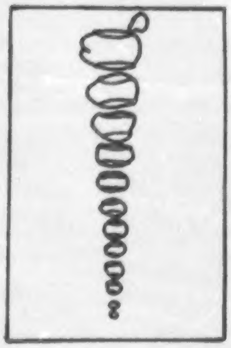


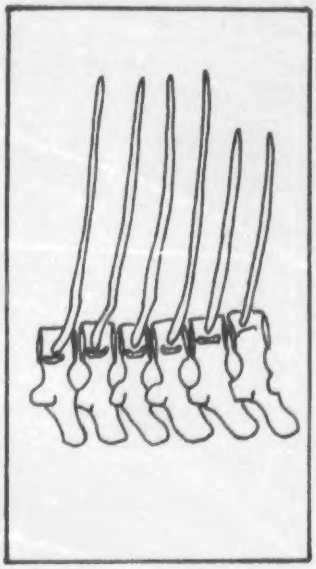
SKELETON SET

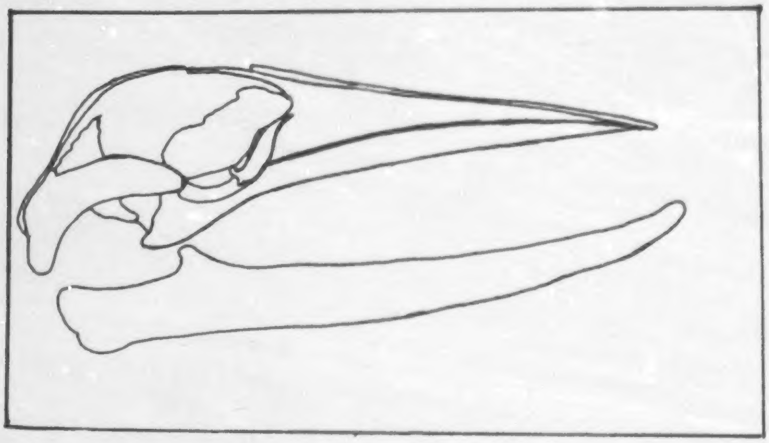
PART A

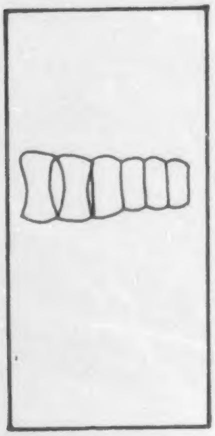


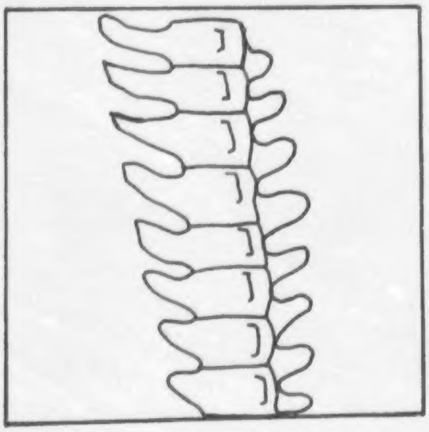


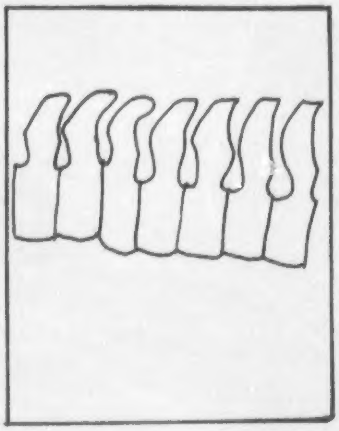






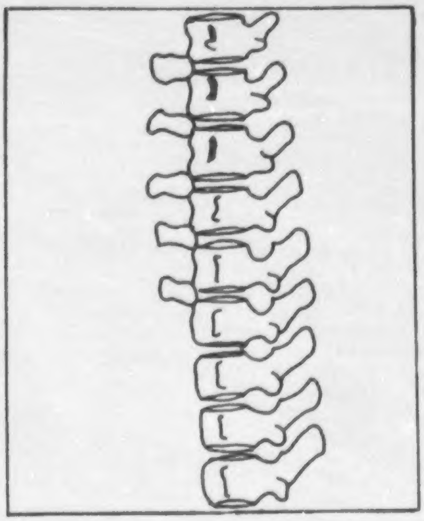


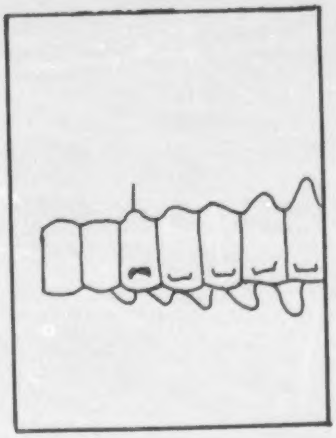


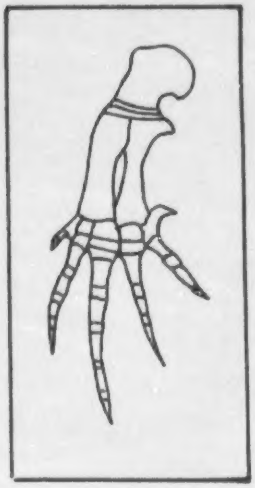


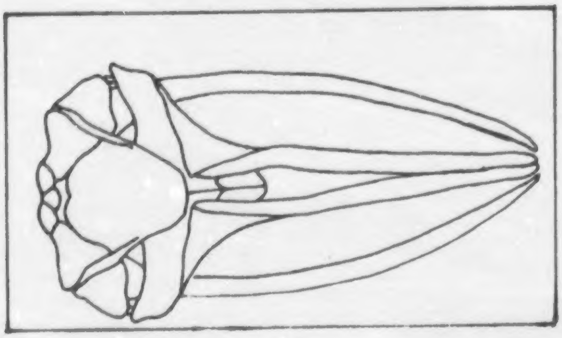
SKELETON SET

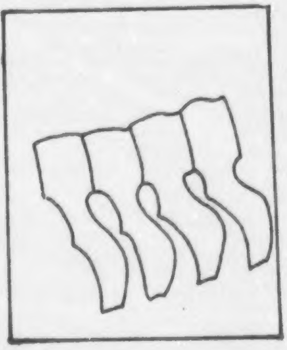
PART A

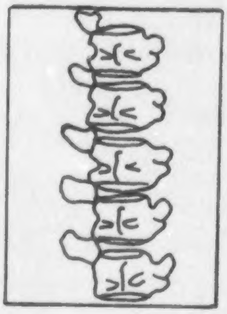


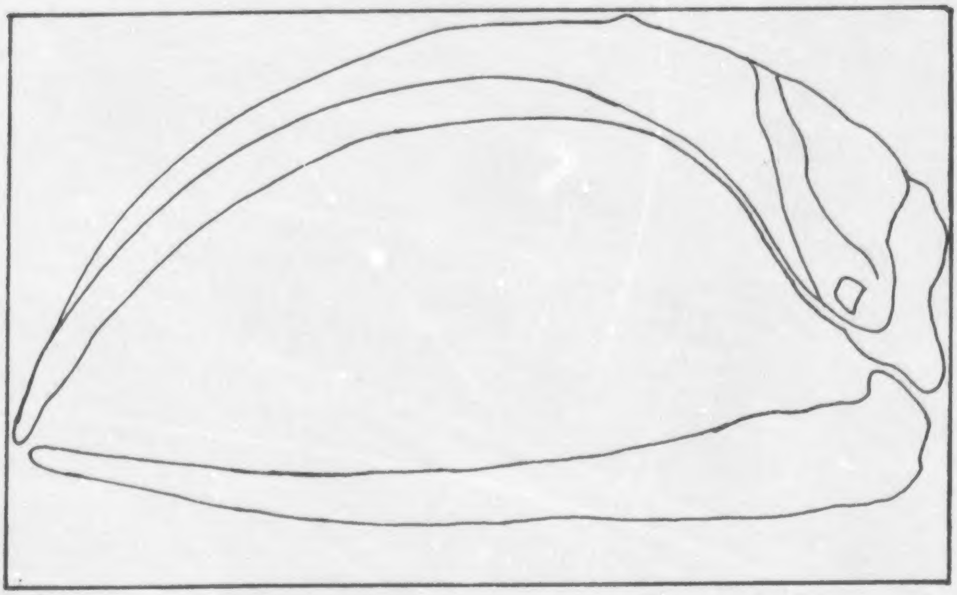


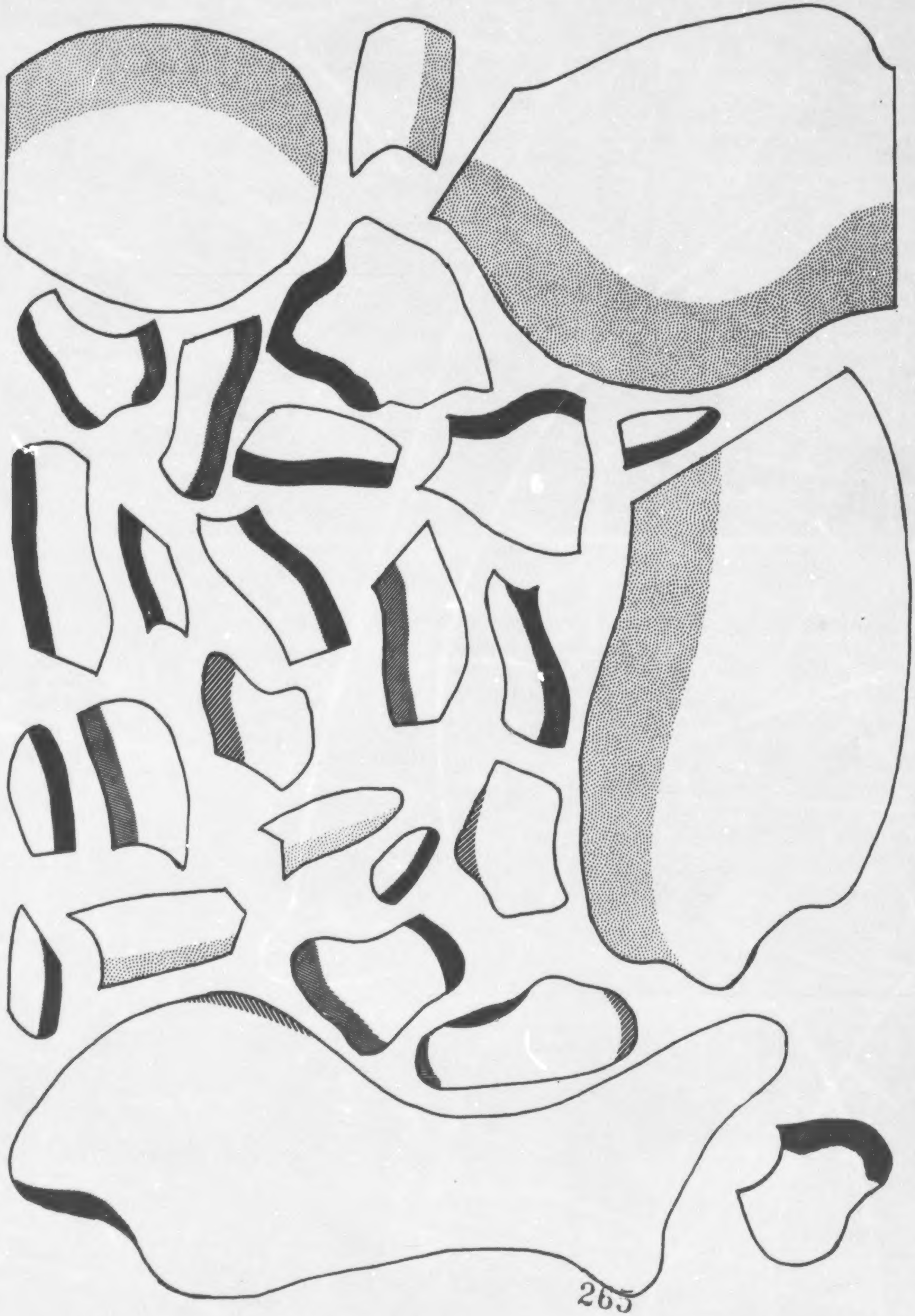










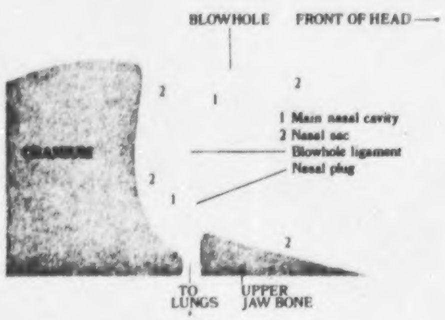


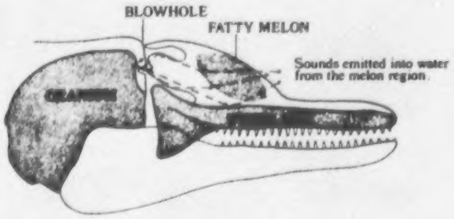
TEACHER BACKGROUND - Earsight

Only within the last three decades has improved technology allowed man to investigate the complex system of underwater hearing used by cetaceans. Studies have shown that cetaceans, unlike sharks and rays, have virtually dispensed with the sense of smell as a method of gaining information about their environment. While the sense of vision is moderately well-developed in some species, vision can only play a limited role in information gathering. This is due to the limited penetration of light in sea water. For example, at a depth of thirty-five meters in the North Sea, 98 percent of the light is extinguished. In addition, at this depth light reflected off objects under water penetrates only a distance of seventeen meters. This distance is so short that a large blue whale cannot even see its own flukes. It now appears that the major information gathering system used by cetaceans centers on the emission of sound waves which create echoes.

The basic principle of echolocation is now widely known. Basically, a short pulse of high frequency waves is sent out and is reflected from any object solid enough to return the waves. The cetacean brain records the time between transmission and reception and combines this time with information about the speed of sound to give the distance to the target. The following diagrams from the Vancouver Public Aquarium Newsletter (Vol. XIX, No. 4), " The Whale Story" summarize our current knowledge regarding sound production and reception in cetaceans.

HOW SOUNDS ARE PRODUCED IN A DOLPHIN


BLOWHOLE
FRONT OF HEAD →
1 Main nasal cavity
2 Nasal sac
Blowhole ligament
Nasal plug
1
2
TO LUNGS
UPPER JAW BONE


BLOWHOLE
FATTY MELON
Sounds emitted into water from the melon region.

The cavity inside the blowhole, called the *nasal cavity*, has a complex structure. Extending from the main part into the head are several pouches, called *nasal sacs*, that may be filled with air. There is also a *blowhole ligament* and a *nasal plug*, both of which are very flexible.

According to many biologists, the sounds are produced by the repeated coming together of the surfaces of the blowhole ligament and the nasal plug. This usually occurs when the blowhole is closed.

Current theory suggests that the peculiar structure of the dolphin head plays a role in orienting the sound pulses before they leave the animal. The skull bones and nasal sacs are able to reflect high-frequency sounds and could serve to direct these to the front of the head.

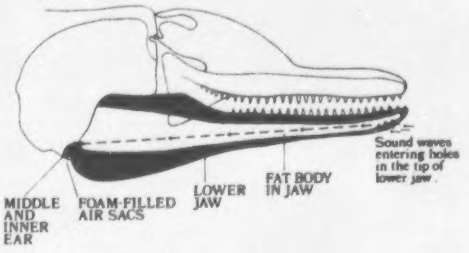
The "forehead" area contains a fatty mass, called the *melon*, which may function as an "acoustic lens". Outgoing sounds are apparently reflected toward the melon. This may then focus the sounds into a directional beam as they leave the head.

HOW THE RETURNING ECHO IS RECEIVED

On each side of the head, the middle and inner ears are encased in a hard bony covering that is separated from the rest of the skull. This hearing unit is, in turn, surrounded by extensive air sacs, filled with foam. Since the foam is an effective sound barrier, the middle and inner ears are insulated from sounds in all directions.

The lower jaw bone is hollow. The cavity of this bone contains a long fat body which is capable of conducting sound pulses in one direction. Also in the space is a nerve that runs to the tip of the jaw where it exits through holes in the bone.

The sound pulses from a returning echo are picked up by the lower jaw, presumably entering this structure through the holes near the tip. The sounds proceed via the fat body to the middle or inner ear.


Sound waves entering holes in the tip of lower jaw.
MIDDLE AND INNER EAR
FOAM-FILLED AIR SACS
LOWER JAW
FAT BODY IN JAW

It appears that three broad groups of sound are used. For information about the topography, low frequency clicks, which have great penetrating power, are used. For communication between members of the same species, somewhat higher frequency whistles are used.

The location of food depends on the highest frequency clicks. Both ears receive information independently, thus giving a directional fix which is then interpreted by the brain. The sophistication of this system allows the cetacean to determine the size, shape, quality and exact location of the object. Additional information about echosounding may be found in the following references from which much of the above information is excerpted:

Dolphins, Whales and Porpoises - An Encyclopedia of Sea Mammals.
1977. David J. Coffey. Macmillan Publishing Co., Inc.
223 pages. See pages 42-43 in particular.

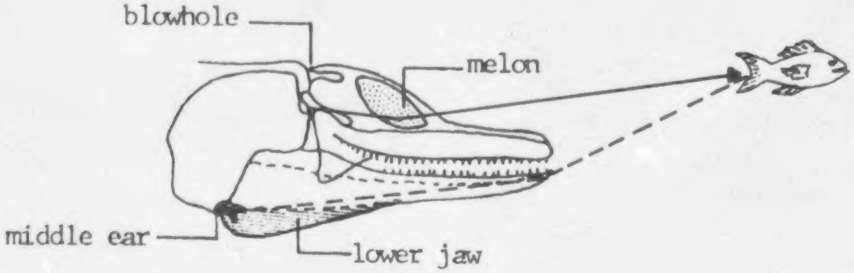
The Natural History of the Whale. 1978. L. Harrison Matthews.
Columbia University Press. 219 pages.
See pages 138-163 in particular.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished in pairs. The background material may be read as a homework assignment prior to initiating the investigation. Any clock or watch with an audible click may be used for this investigation. Since the number of clocks is often the factor which determines group size, you may elect to encourage your students to bring in clocks from home. Maintain the lowest noise level possible during the course of the investigation. If your students have trouble keeping their eyes closed, you may provide them with optional blindfolds to help assuage their curiosity. A preview reading makes the procedure much easier to follow. Circulate through the room as the investigation is being performed. Provide your students with any help necessary for successful completion. Plan to spend some time in a discussion of the procedure and the questions found in the "Analysis and Interpretation" section.

KEY

Text Question

1. A correctly labeled dolphin skull is shown below.



Analysis and Interpretation

Part A.

1. a. While the answer depends upon the experimental results, it is unlikely that the right ear distances for Trials 1 and 2 are the same.
   b. The answer depends upon the experimental results.
2. a., b. See answers to 1 above
3. a. Again, while the answer depends upon the experimental results, it is unlikely that the right ear and left ear distances or averages will be the same. Your students will be able to come up with many plausible reasons for the differences including injury to one ear, more noise during one of the trials, the improvement due to practice, etc. The differences also reflect the variation inherent in physiological systems.
   b. Since this question asks for an opinion, there is no right answer. A reasonable case can be made that it is more important for whales to have equal hearing distances since they rely more heavily on hearing to sense their environment. However, it is not at all certain that equal hearing abilities are required to have echolocation work well. It is more likely that the brain of both man and whale compensate for any slight differences in auditory acuity. This question is included to provide an opportunity for a discussion of the role of hearing in man versus whale.

4. a. While the answers will vary in direct proportion to the vanity of your students, none of your students abilities will begin to compare with those of the sperm whale.
   b. Practice will in all likelyhood improve your students' ability. Supporting data might include an increase in distance from the right ear Trial 1 to left ear Trial 2.
5. a., b., c. The answers depend upon the experimental observations.
   d. This question asks for an opinion. As such, there is no right answer. Hopefully, your students will be able to generalize from the variability they saw in humans to the variability which exists in whales.

Part B.

1. The answer depends upon the experimental results.
2. Data which supports the idea of an improvement with practice might include an increase in accuracy from position 1 to position 4.
3. Besides location, whales can tell the size, and quality of the object.
4. The whale's well-developed sense of echolocation helps it to survive in several ways:
   a. food location
   b. collision avoidance
   c. orientation (the whale can determine where she is in relation to other objects and organisms).
   d. species and/or mate recognition.

   Other suggestions are also possible. Two ways are required.
5. In the ocean environment, echolocation seems to be a more "important" sense than vision because of the limited penetration of light beneath the surface and the highly limited distance reflected light can travel beneath the surface. You are wise to point out that it is artificial to term one sense more important than another. All of the senses, in fact, apparently all of the things an animal does, have proven to have evolutionary significance - they help the animal survive. Man alone ranks the importance of the various adaptations. This may lead to a dangerous (even fatal) error in judgement on our part. Often, the things we term insignificant turn out to be highly significant for long term survival of the species in question (be it dolphins or man).

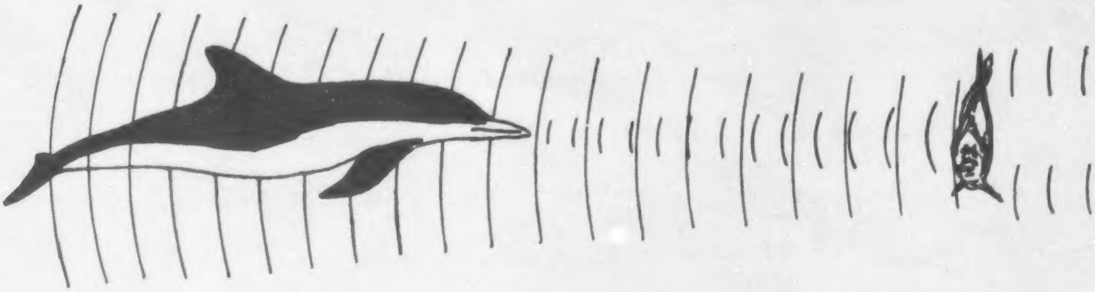
KEY WORDS

amplifier
ancestor
auditory
average
baleen whales
blowhole
cetaceans
comparable
dolphin
echo
echolocation
environment
eyesight
high frequency
melon
middle ear
penetrates
primitive
porpoise
sense
squid
three-dimensional
toothed whales
vision
well-developed
whale

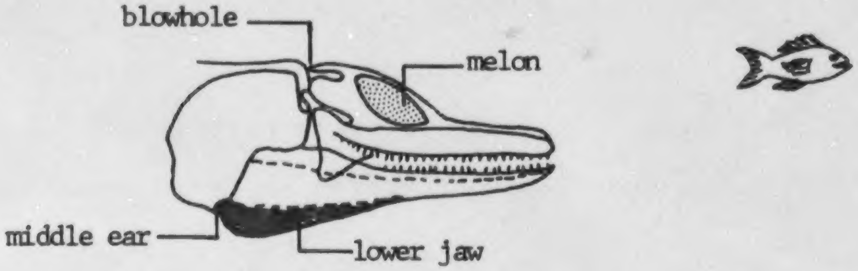
EARSIGHT

The primitive ancestors of whales, dolphins, and Porpoises lived on land. To survive, these primitive animals needed good eyesight. Modern cetaceans (whales, dolphins, and porpoises) also have fairly good eyesight. Unfortunately, most of the ocean's waters are poorly lighted or totally dark. Only ten percent of the light hitting the ocean surface penetrates as far down as 30 feet. With limited light, vision (sight) is less effective. The cetaceans cannot depend upon vision to guide them to their food. What senses do they use?

Whales, dolphins and porpoises depend on their sense of hearing to guide them to food. These cetaceans have the ability to detect objects in the water using high frequency sounds. This ability is similar to that used by bats to catch flying insects.



The sounds are produced inside the blowhole. In toothed whales a beam of sound passes forward out of the head through the melon or "forehead". Any objects in the surrounding water then give off echoes. These echoes are received in the lower jaw, which then sends them to the middle ear.



1. The above diagram shows a cross section of a dolphin skull.
   a. On the diagram use solid arrows to trace the path of sound waves from the blowhole to the melon and then to the fish.
   b. Use dotted arrows to trace the path of sound waves from the fish to the tip of the lower jaw, then through the jaw to the middle ear.

The well-developed auditory (hearing) areas of the cetacean brain receive the messages. From the nature of the echoes, the brain can determine the size, quality, shape and exact location of an object.

This whole process is called echolocation. Echolocation provides the cetacean with a three-dimensional view of its surroundings. Thus, whales, dolphins and porpoises "see" with their ears, as we do with our eyes. Most studies have involved toothed whales. There is, however, evidence that at least some baleen whales also use echolocation. Humans, through the use of special amplifiers, continue to study echolocation by cetaceans. These amplifiers transform the high frequency sound into a series of clicks or pings. The following activity will help you determine your echolocation skills.

Materials:

clock, non-electric
long, clean table or counter
meter stick

Procedure:

For this activity you will work in pairs. Read the procedure through before starting.

Part A.

1. Obtain a clock and a meter stick.

2. Sit at one end of the table. Put your right ear flat against the table top. Place your hand flat over your other ear to reduce the sounds entering that ear.

3. Have your partner put the clock at the other end of the table.

4. Tell your partner you are ready to begin. Close your eyes and keep them closed until you are told to open them. Use your special creativity to imagine that you are a sperm whale and the clock is a squid, your favorite food.

5. When your eyes are closed, your partner will say "I am going to move the clock toward you. When you first hear the clock, raise your hand."

6. After you raise your hand, open your eyes. Have your partner measure the distance from your ear to the clock. Record this distance:________________centimeters.

7. Repeat steps 2 to 6 using your left ear. Record this distance: ___________centimeters.

8. Now repeat steps 2 through 7 to obtain a second set of data for your ears. Record these distances below:

Trial 2 Right Ear Distance: ____________centimeters.

Trial 2 Left Ear Distance: ____________centimeters.

9. Switch roles and have your partner determine his hearing vision. Record your partner's results in the spaces below:

Trial 1 Right Ear Distance: _____________centimeters.

Trial 1 Left Ear Distance: _____________centimeters.

Trial 2 Right Ear Distance: ____________centimeters.

Trial 2 Left Ear Distance: ____________centimeters.

Part B.

Whales and other cetaceans use echolocation to do more than judge the distance to an object. They can tell the size, quality and exact location of the object. In Part B, you will see how well you can estimate the depth and position of your "squid".

1. Again, sit at one end of the table. Put your right ear flat against the table top. Place your hand over your other ear to reduce the sounds entering that ear.
2. Tell your partner you are ready to begin. Close your eyes and keep them closed until you are told to open them.
3. When your eyes are closed, your partner will say "I am going to move the clock. When you first hear the clock, raise your hand. Tell me where the clock is on the table. Keep your eyes shut". Your partner will move the clock to four different positions on the top, underneath the table, and on the table legs. (The clock must remain in contact with the table.)
4. Estimate the depth and position of the squid for all four positions. Your partner will record your answers (the apparent location) along with the actual location of the squid (clock).

Position	Actual Location	Apparent Location
1		
2		
3		
4		

5. Switch roles and have your partner determine her hearing vision. Record your partner's results in the space below:

Position	Actual Location	Apparent Location
1		
2		
3		
4		

6. Return the clock and meter stick. Answer the following questions.

Analysis and Interpretation:

Part A

1. a. Are the right ear distances the same for Trial 1 and Trial 2? If they are, what was the distance?

   b. If the distances are not the same, find the average distance for the right ear. (Hint: this is easy. To find the average add the two distances and divide the sum by 2) The average distance for the right ear is ____________centimeters.

2. a. Are the left ear distances the same for Trial 1 and Trial 2? If they are, what was the distance?

b. If the distances are not the same, find the average distance for the left ear.

The average distance for the left ear is__________ centimeters.

3. a. Are the right ear and left ear distances or averages the same? If not, what might explain the differences?

b. Do you think it is more important for whales or for man to have equal hearing distances for right and left ear? Why?

4. a. With your present "squid hunting" ability, do you think you would make a good sperm whale?

b. Do you think that you might be able to improve your ability with practice? Does any of your data support your answer?

5. Compare your results with those of your partner.

a. Are your right ear distances the same? If not, what is the difference in centimeters?

b. Are your left ear distances the same? If not, what is the difference in centimeters?

c. Which of you could hear the squid at the greatest distance?

d. Do you think that all whales have equally good echolocation abilities? Upon what do you base your answer?

Part B.

1. I was able to correctly locate the squid in zero, one, two, three, four locations (Circle the correct answer).

2. Did your ability to locate the squid improve with practice? If so, what data supports your answer?

3. In this activity you tried to locate the position of the squid. Besides location, what can whales tell about an object by echolocation?

4. What are two ways in which the whale's well-developed sense of echolocation helps it to survive?

   a.

   b.

5. Why does echolocation seem more important than vision in the ocean environment?

MARINE FOOD CHAIN DYNAMICS

TEACHER BACKGROUND - String For Your Supper

Food chains are relatively easy for your students to comprehend. These simple diagrams which show feeding relationships provide information in support of three basic concepts:

a. Living things are dependent upon each other and upon their non-living environment.

b. The sun is the ultimate source of the energy used by all living systems.

c. The most stable communities are those with the greatest diversity. A stable community is one which is able to resist disruption.

"String For Your Supper" provides your students with an opportunity to construct a food web mobile comprised of marine food chains. The food web provides a springboard for a discussion of the interrelationships required to maintain a living community.

Duplicate the activity pages and the organism cards. For best results duplicate the cards on heavy paper or card stock. One set of activity pages is recommended per student. This activity may be performed by individual students or by small groups. The number of card sets required is dependent upon the group or class size. Your students may need an introduction to mobile making and the art of finding the center of balance. For ease of construction, the organism cards and cut-out animals indicate, in writing, by whom they are eaten. This information should result in a standardized mobile which will provide the information needed to answer the text questions. A schematic diagram of the mobile follows this "Teacher Background" section.

The display of a completed mobile, preferably a different mobile than the one your students will be assembling, is most helpful. After your students have completed their mobiles, provide a place to display them. You may facilitate this display by providing pre-hung threads from the ceiling, light fixtures, etc. Upon completion, plan to discuss the activity and the "Analysis and Interpretation" questions. As a "One Step Further...." activity you may have your students construct food chain mobiles using pictures of marine organisms taken from magazines and other similar sources.

KEY

1. In a correctly assembled mobile, the lowest level has the greatest number of organisms.
2. a. The highest or top level (the toothed whale and the baleen whale) has the fewest organisms.
   b. The number of organisms at each level decreases as you move up the pyramid. This is an important concept and one that deserves emphasis. This concept is often called the pyramid of numbers.
3. a. The primary producers form the bottom layer of the mobile. This question is designed to reinforce the concept that the entire food web of the ocean depends upon the primary producers.
   b. Since each of the first order consumers "feeds" on two primary producer cards, the removal of one primary producer has a limited effect. The first order consumer can simply increase its consumption of the remaining primary producer card.
   c. The removal of several primary producers has a different effect. Some of the first order consumers are now without food and will die. The death of these first order consumers adversely influences the second order consumers that feed upon them and so on up the chain. Emphasize the point that the food web is resilient enough to absorb the loss of some of its members. The more links in the food web, in general, the more losses the system can sustain without collapse. The stability of the system is dependent upon its diversity.
4. a. Third order consumers eat second order consumers. This deduction follows from the text.
   b. Write the names of your organisms in the proper space below:

Primary producer	1st order consumer	2nd order consumer	3rd order consumer
phytoplankton	*zooplankton*	*squid*	*sperm whale*
(12 cards)	*(6 cards)*	*sablefish*	
		gray whale	

5. a. The first order consumers form the second level (from the bottom) of the mobile.
   b. Removal of one of the first order consumers has a limited effect on the food web because each first order consumer shown has two primary producers upon which it feeds.
   c. The removal of several first order consumers has a more serious effect. Depending upon the particular first order consumers removed, the gray whales, the squid or the sablefish could find themselves without food. If no suitable alternate prey was available, the second order consumer in question would starve.
   d. The removal of several primary producers did more damage than the removal of several first order consumers. The lower an organism is on the food chain, the greater its potential impact when it is eliminated. The removal of any organism affects all of those that are above it on the food chain.
6. a. The final consumers are the spermwhale (third order consumer) and the gray whale (second order consumer).
   b. The number of animals that feed on the sperm whale and/or the gray whale is limited. Man is about the most significant animal that could be added to the top of the mobile.
7. Phytoplankton make up the base of the food pyramid in the mobile. This question reemphasizes the notion that primary producers are the foundation for the entire food web.
8. Destruction of the lowest level (the primary producers) would have the greatest effect on the other organisms.

9. a. The more complex the mobile, the *more*/[✓ *less*] change will occur from the removal of one organism (the correct answer is circled.) This is so because the most stable communities of plants and animals are those with the greatest diversity. (Emphasize that it is important for us to recognize this concept when we begin to simplify communities by harvesting plants and animals).

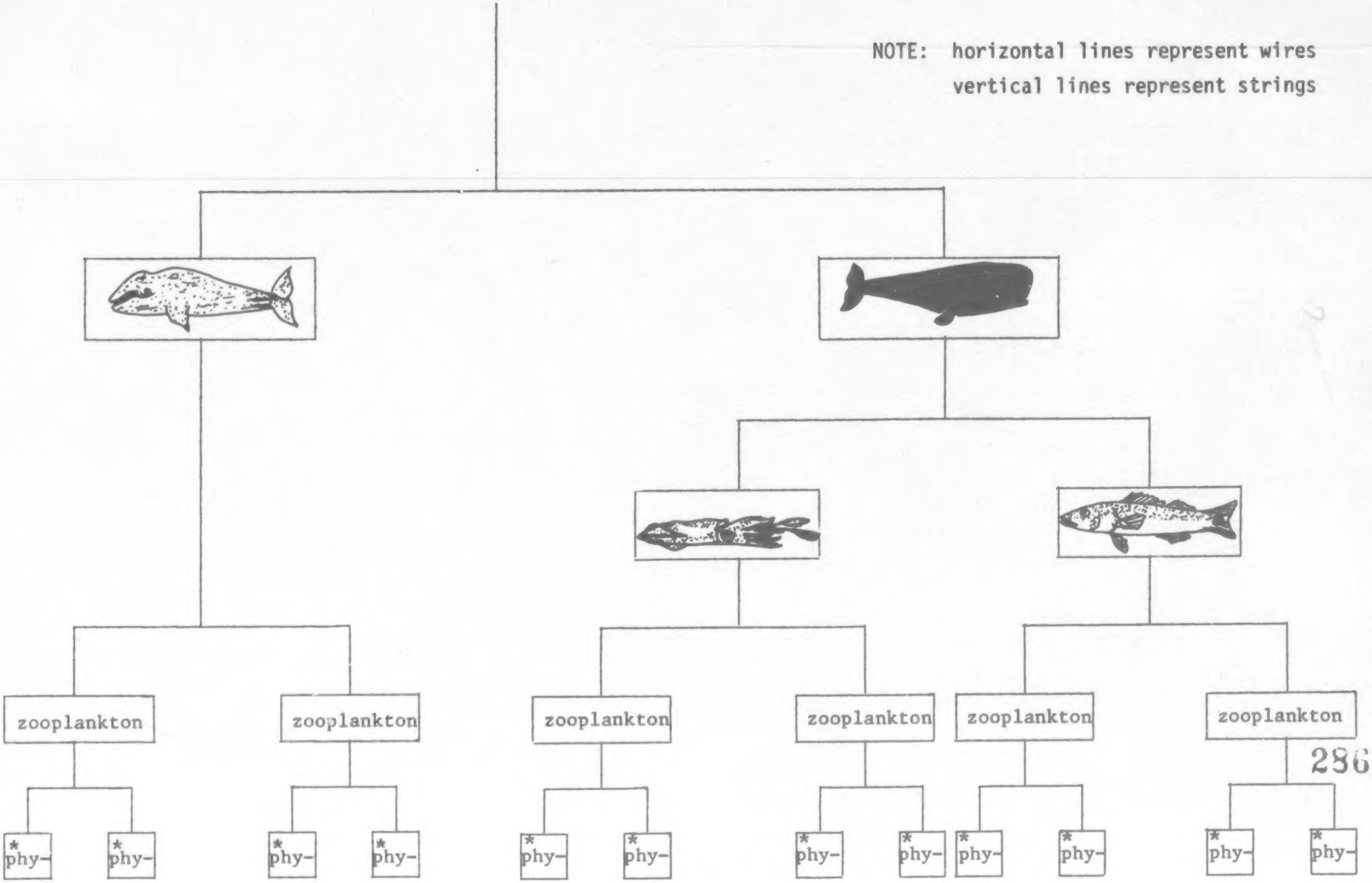
b. In the above sentence, diversity means, *the variety of plants and animals, present in the community.*

10. Man is most likely to harm [✓ *simple*]/*complex* communities of plants and animals. (The correct answer is circled.) (This question can provide a springboard for further discussion of the effect of man's actions on aquatic ecosystems).

KEY WORDS

carbon dioxide
community
diversity
environment
first order consumers
food chains
food pyramid
food web
liter
mobile
organism
phytoplankton
primary producers
second order consumers
stable
third order consumers
zooplankton

NOTE: horizontal lines represent wires
vertical lines represent strings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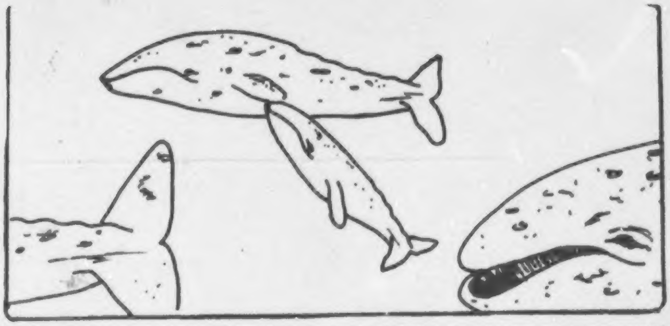


STRING FOR YOUR SUPPER

Plants and animals depend upon each other and their environment for the things they need to live. One of the basic requirements for all animals is food. We have seen that some of the biggest animals in the sea eat some of the smallest. Life in the oceans begins with phytoplankton, drifting plants. Most phytoplankton are very small. Phytoplankton use carbon dioxide and water, plus energy from the sun, to grow. A single liter of sea water may contain millions of phytoplankton.

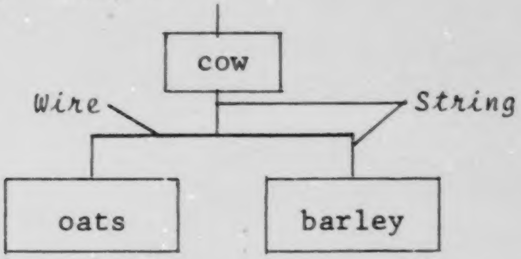
The zooplankton, or drifting animals, eat phytoplankton and each other. Practically all life in the sea depends directly or indirectly upon phytoplankton and zooplankton. The relationships of who eats whom form food chains. The chains join to form food webs. In the following activity you will have an opportunity to create a food web of your own.

Materials:

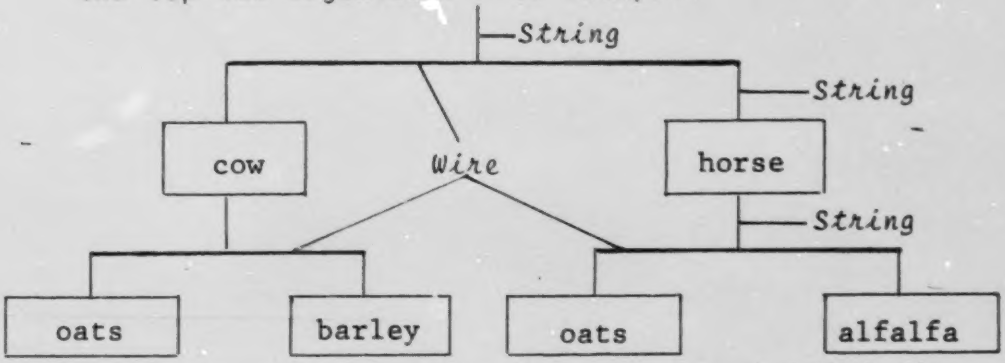
- organism card
- scissors
- hole punch
- strong thread
- wire (about 12" long pieces of coathanger) or wooden dowels or straws

Procedure:

1. Obtain a set of organism cards and a pair of scissors. Cut out the cards.
2. With the hole punch, punch out the marked dot on each card.
3. Use string and wire to connect the eaters and the eatens. For example:


cow
Wire
String
oats
barley

4. To finish your mobile, use string and wire to connect the top two organisms. For example:


String
String
cow
Wire
horse
String
oats
barley
oats
alfalfa

5. Hang your mobile and use it to answer the following questions.

Analysis and Interpretation:

1. Which level of the mobile has the greatest number of individual organisms?

2. a. Which level has the fewest organisms?

   b. In general, what happens to the number of organisms as you move up the mobile?

3. a. Primary producers are organisms that make their own food. The primary producers in the ocean are the phytoplankton. Where are the primary producers in your mobile?

   b. What happens to the animals above if you remove one primary producer?

   c. What happens if you remove several primary producers?

4. First order consumers are animals which eat primary producers. They are first to eat the producers. Second order consumers are animals which eat first order consumers.
   a. What do third order consumers eat?

   b. Write the names of your organisms in the proper space below:

Primary Producer	1st order consumer	2nd order consumer	3rd order consumer

5. a. Where are the first order consumers in your mobile?

   b. What happens when you remove one of the first order consumers?

   c. What happens when you remove several first order consumers?

   d. Did the removal of several first order consumers do more or less damage to your mobile than the removal of several primary producers?

6. a. What are the final consumers in your mobile?

   b. What animal could you add to the top of your mobile?

7. A food web such as you have made can also be called a food pyramid. What organisms make up the base of your food pyramid?

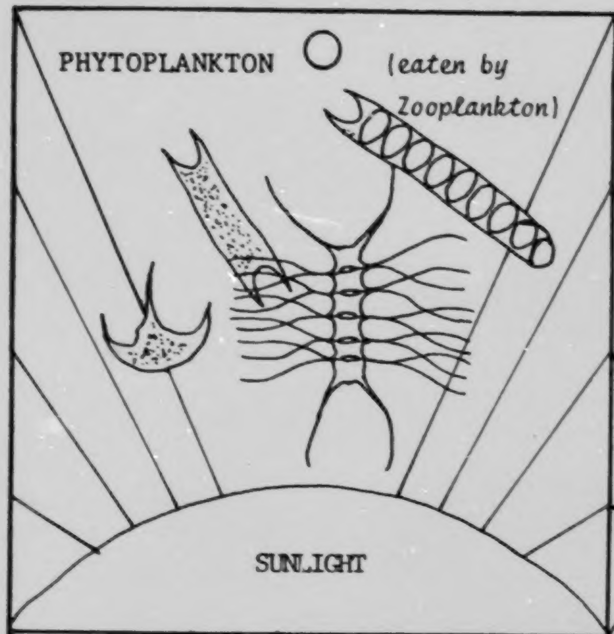
8. Destruction of which level would have the greatest effect on the other organisms?

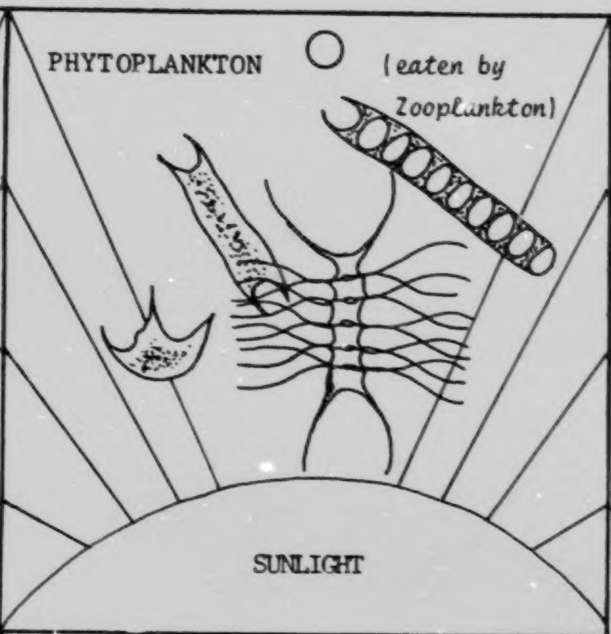
9. a. The more complex the mobile, the more / less change will occur from the removal of one organism. (Circle the correct answer.) This is so because the most stable communities of plants and animals are those with the greatest diversity.

b. In the above sentence, diversity means ____________

____.

10. Man is most likely to harm simple / complex communities of plants and animals. (Circle the correct answer.)


PHYTOPLANKTON ○ (eaten by Zooplankton)
SUNLIGHT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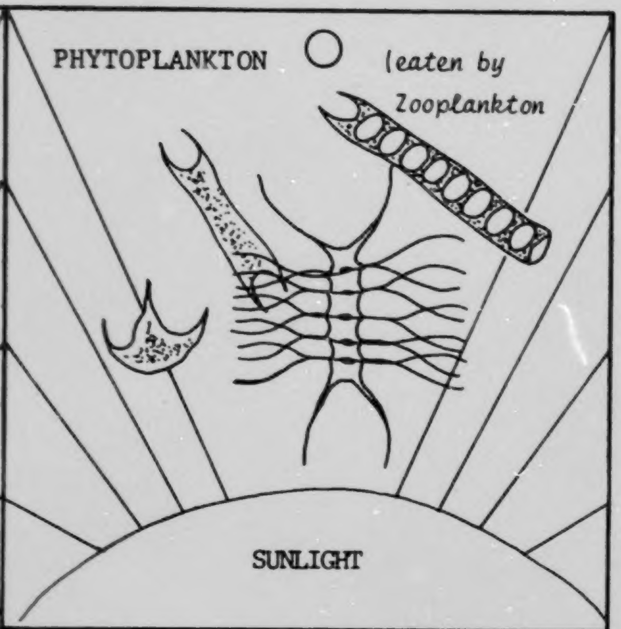
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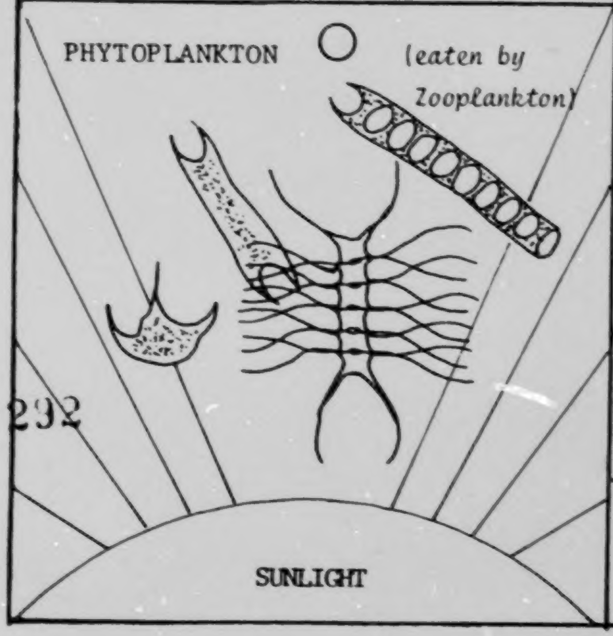
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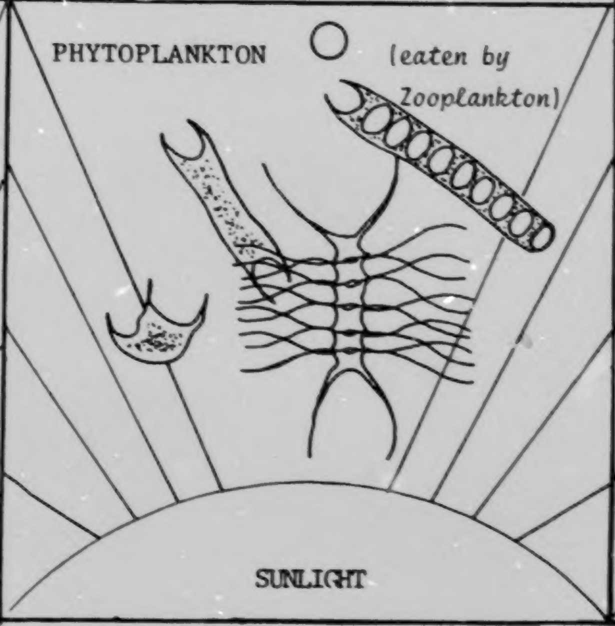
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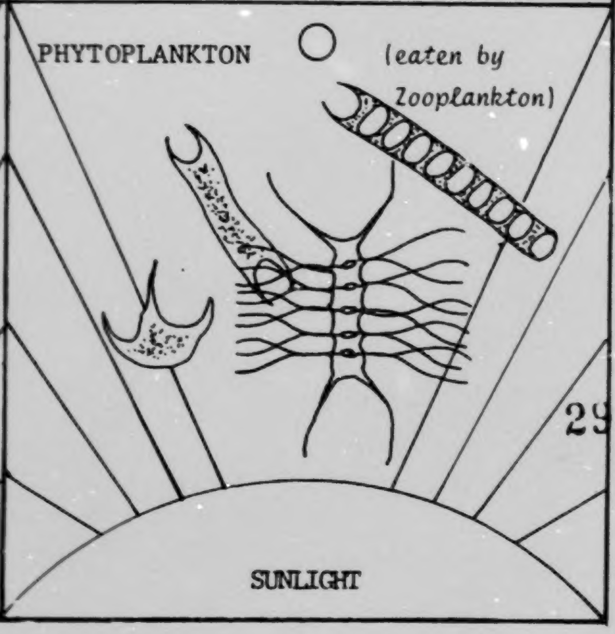
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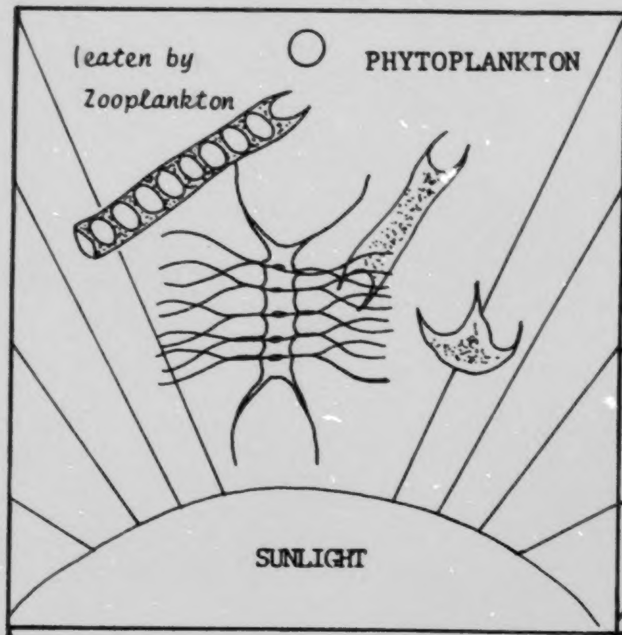
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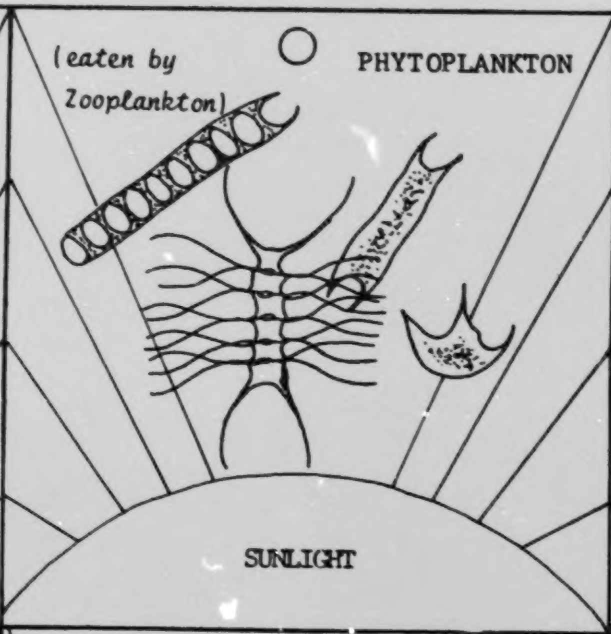
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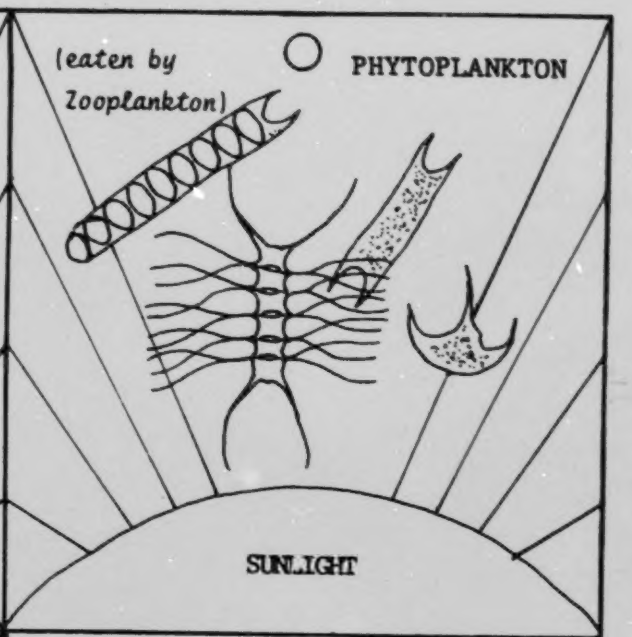
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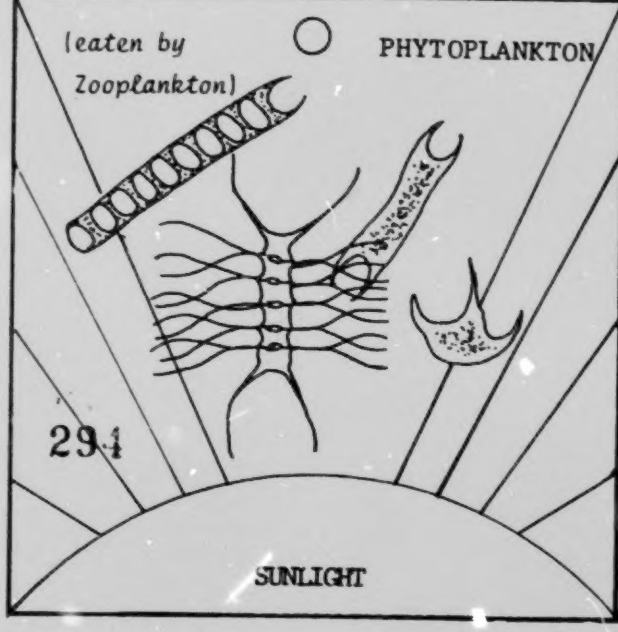
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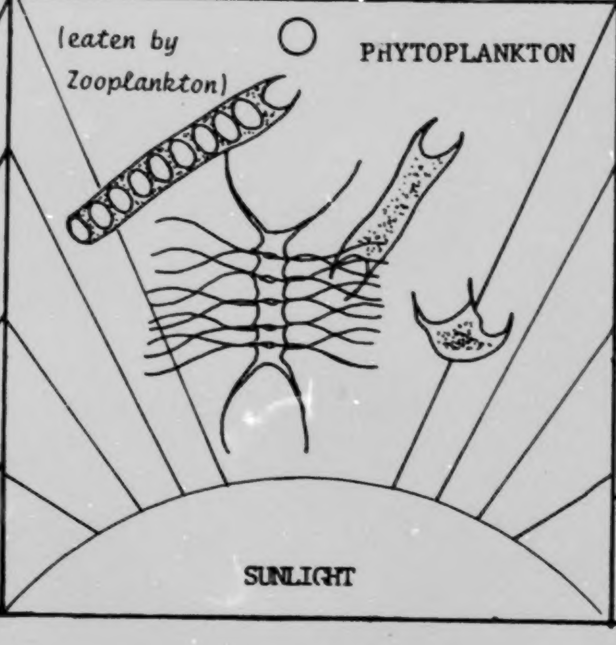
(eaten by
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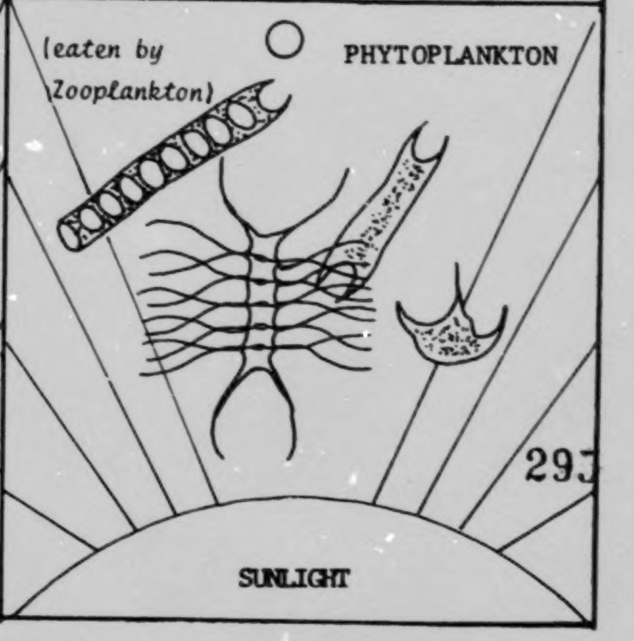
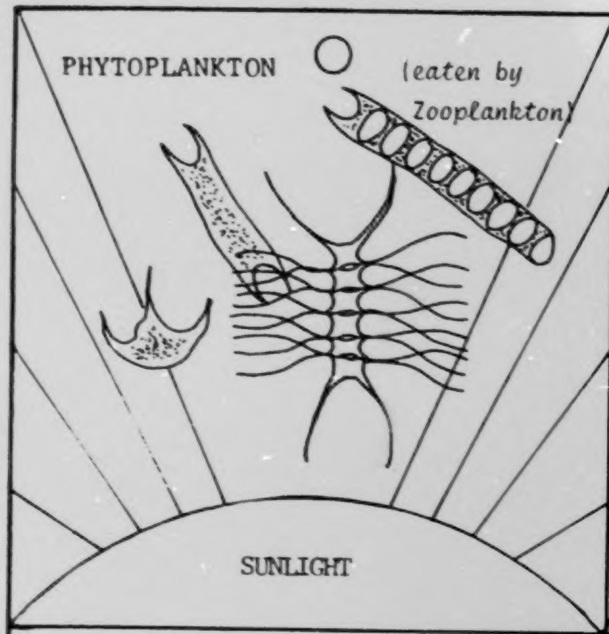
PHYTOPLANKTON
SUNLIGHT


(eaten by
Zooplankton)
○
PHYTOPLANKTON
SUNLIGHT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(eaten by Zooplankton)
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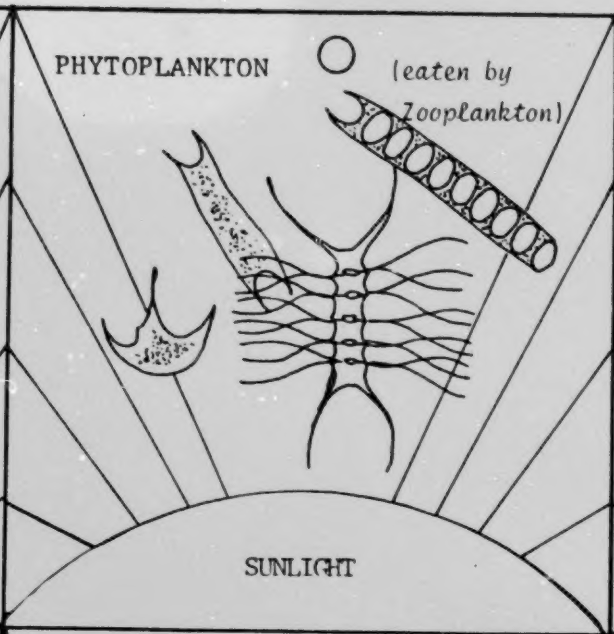
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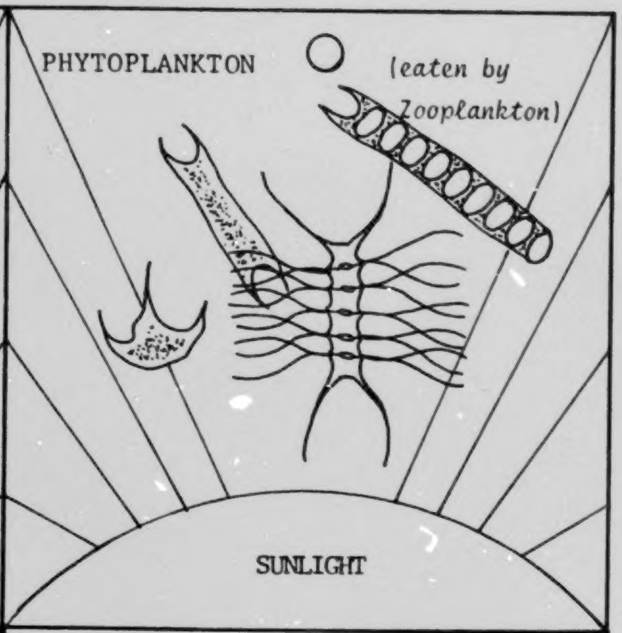
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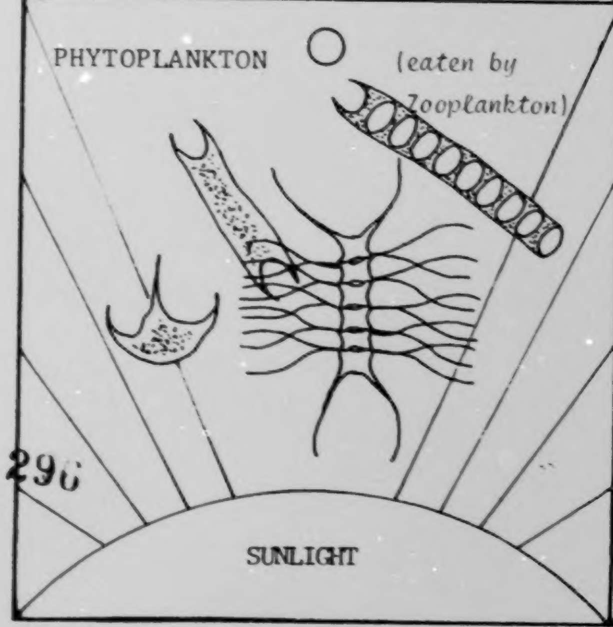
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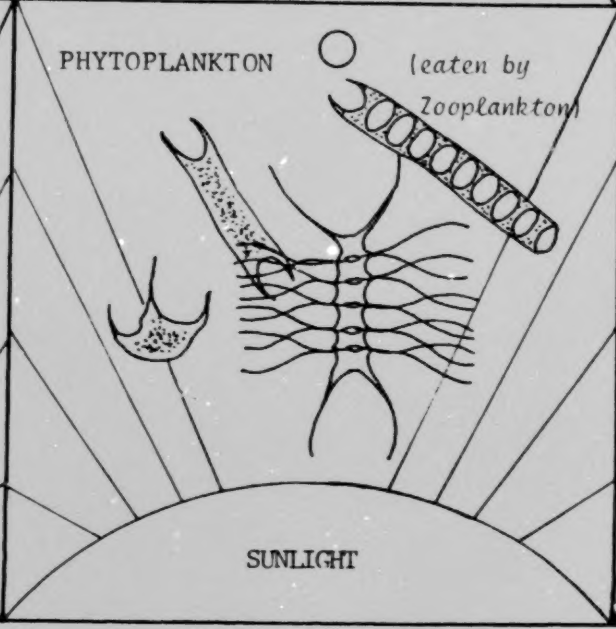
SUNLIGHT

296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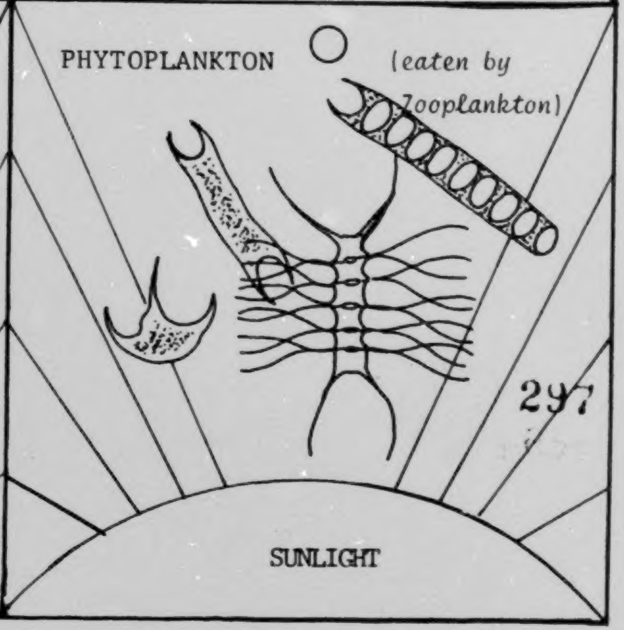
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(eaten by Zooplankton)
SUNLIGHT

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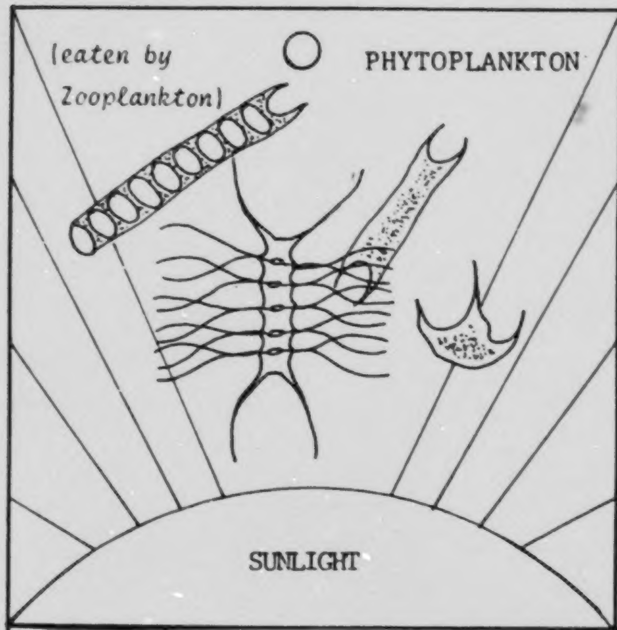
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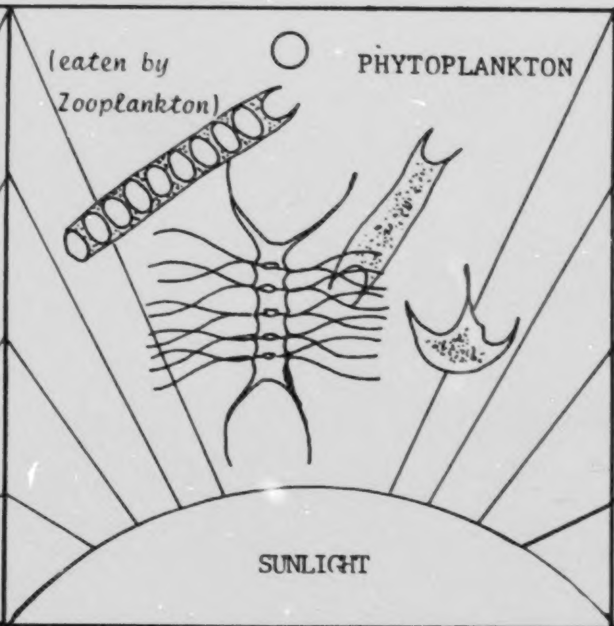
Zooplankton)
PHYTOPLANKTON
SUNLIGHT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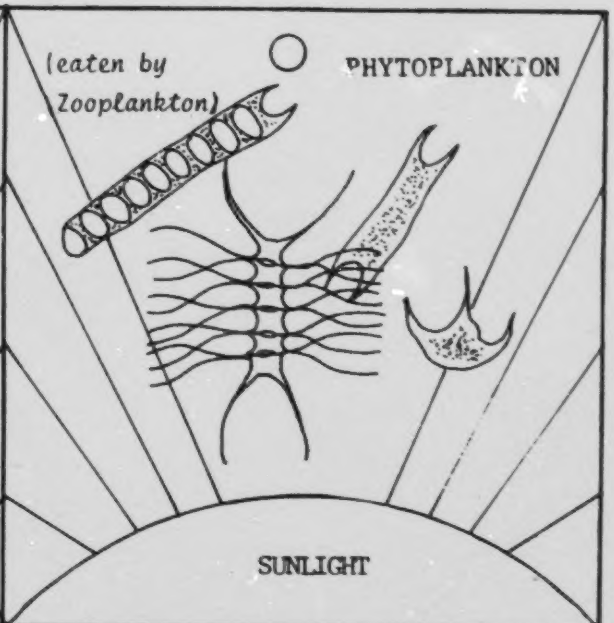
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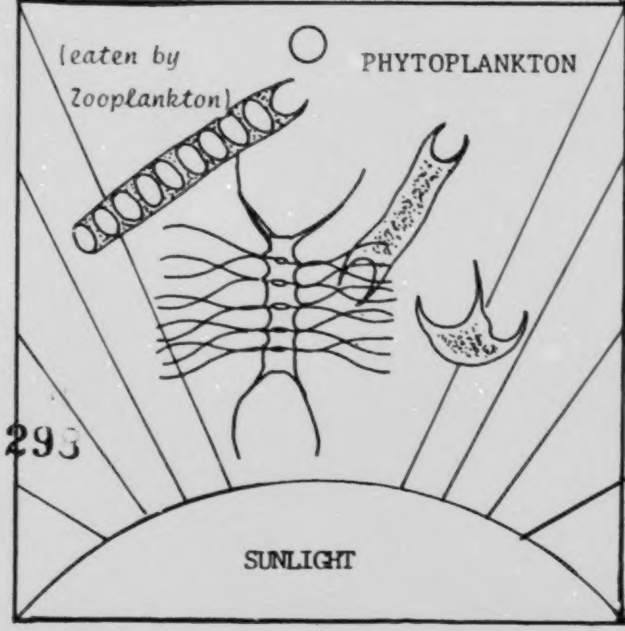
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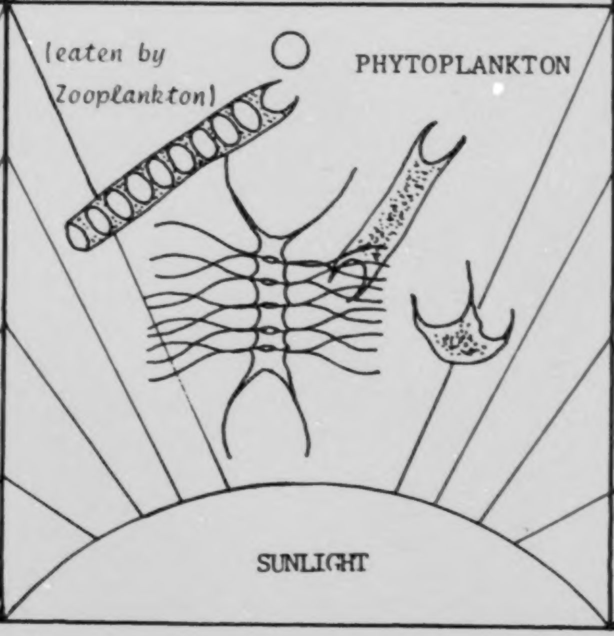
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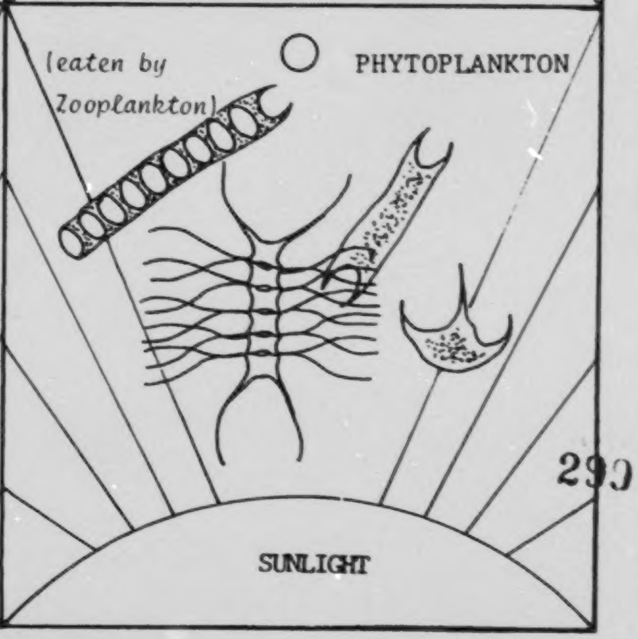
PHYTOPLANKTON
SUNLIGHT


(eaten by
Zooplankton)
PHYTOPLANKTON
SUNLIGHT

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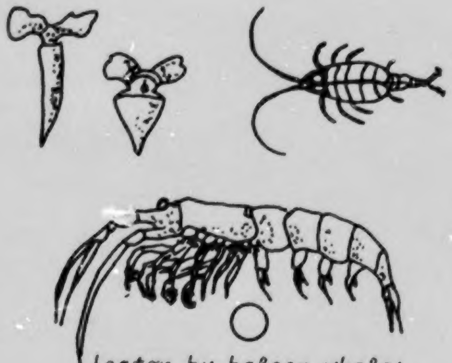
ZOOPLANKTON



(eaten by baleen whales, sablefish and squid)

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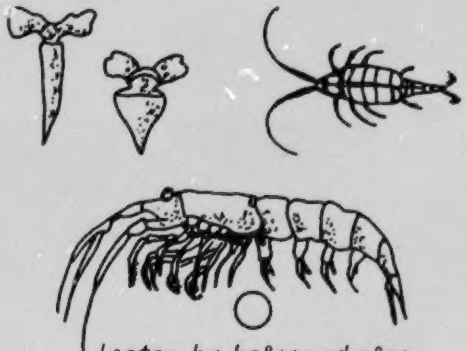
ZOOPLANKTON



(eaten by baleen whales, sablefish and squid)

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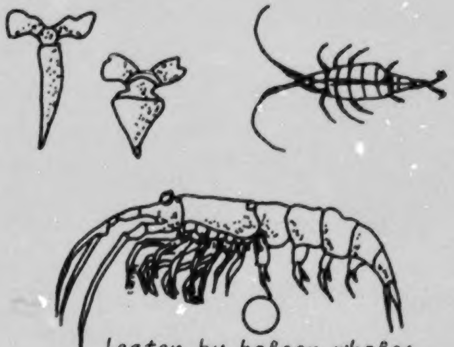
ZOOPLANKTON



(eaten by baleen whales, sablefish and squid)

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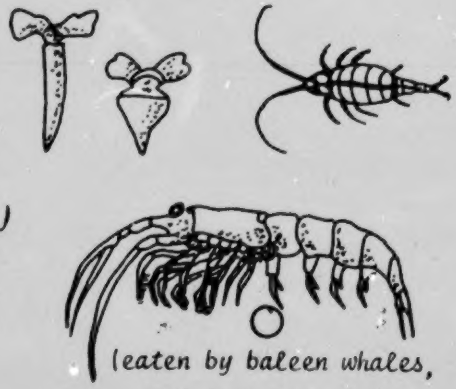
ZOOPLANKTON



(eaten by baleen whales, sablefish and squid)

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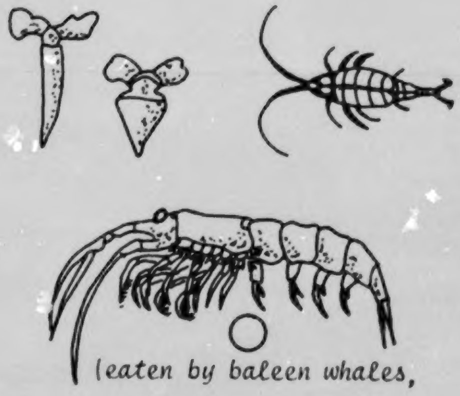
ZOOPLANKTON



(eaten by baleen whales, sablefish and squid)

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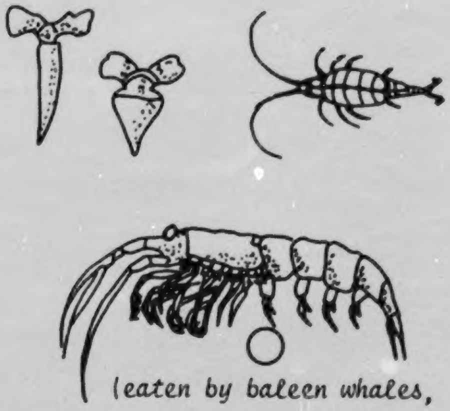
ZOOPLANKTON



(eaten by baleen whales, sablefish and squid)

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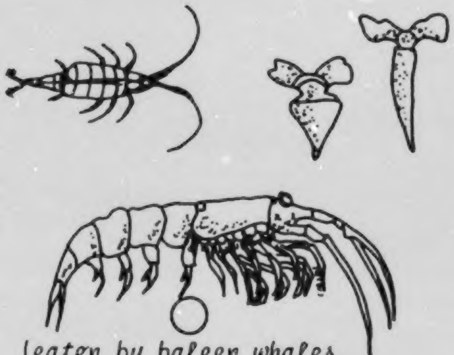
ZOOPLANKTON



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(eaten by baleen whales, sablefish and squid)

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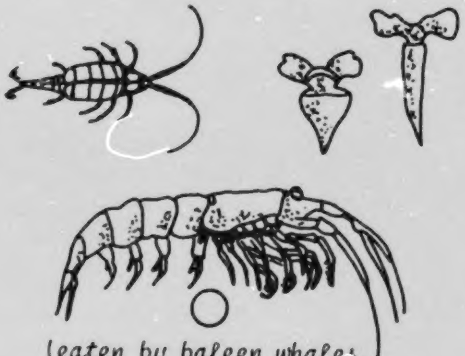
ZOOPLANKTON



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(eaten by baleen whales, sablefish and squid)

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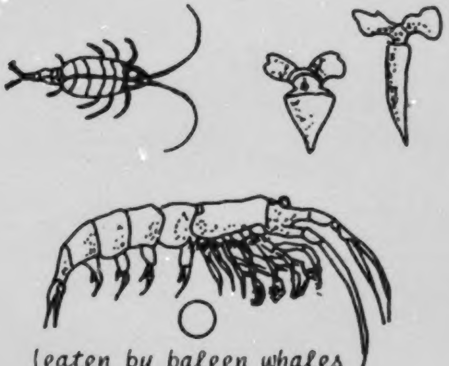
ZOOPLANKTON



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(eaten by baleen whales, sablefish and squid)

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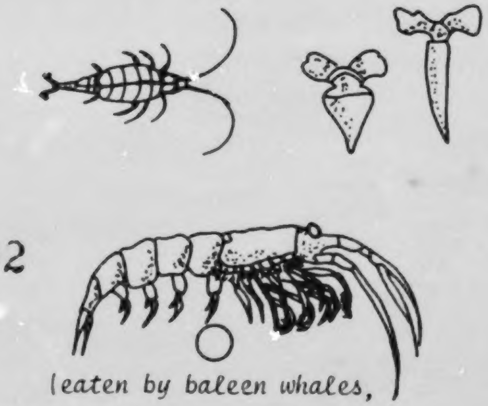
ZOOPLANKTON



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(eaten by baleen whales, sablefish and squid)

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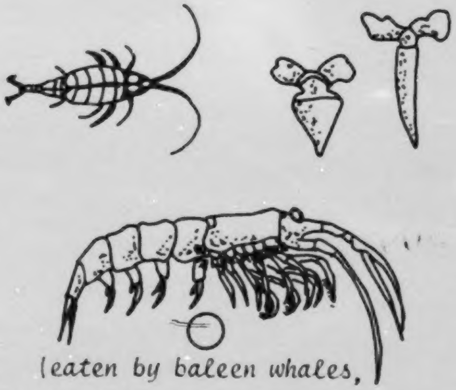
ZOOPLANKTON



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(eaten by baleen whales, sablefish and squid)

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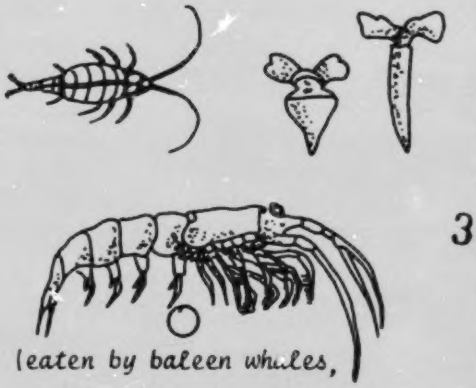
ZOOPLANKTON



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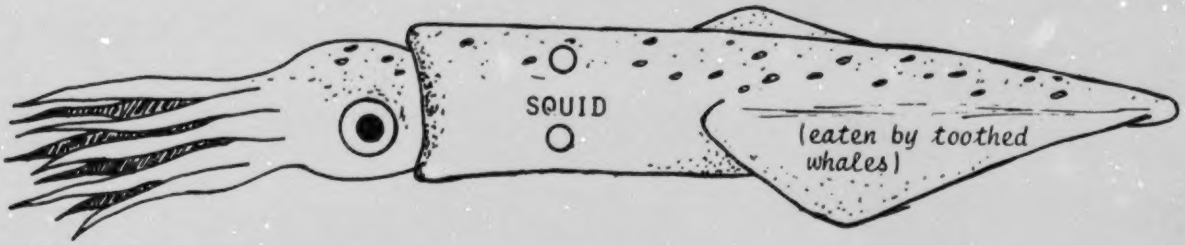
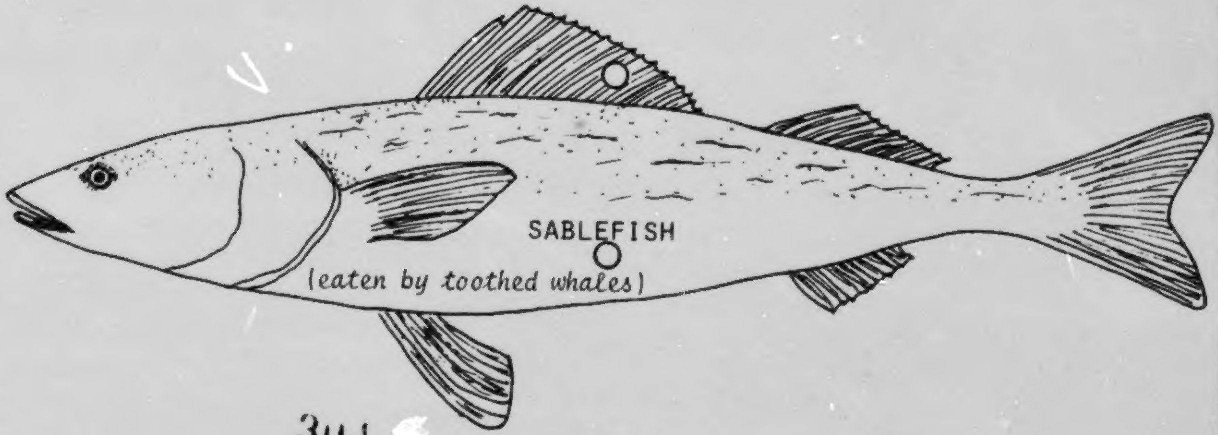
(eaten by baleen whales, sablefish and squid)


SQUID
(eaten by toothed whales)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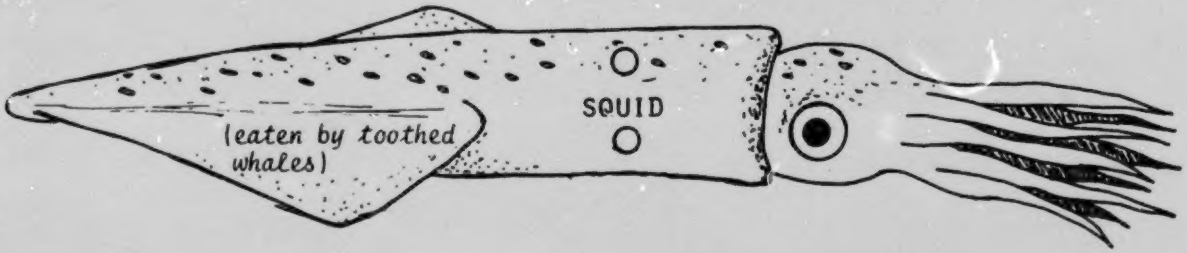
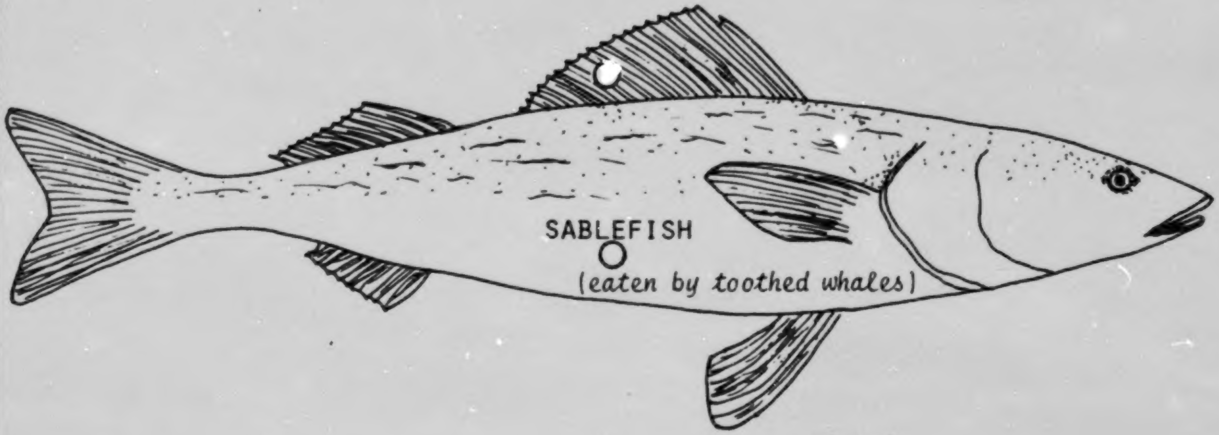
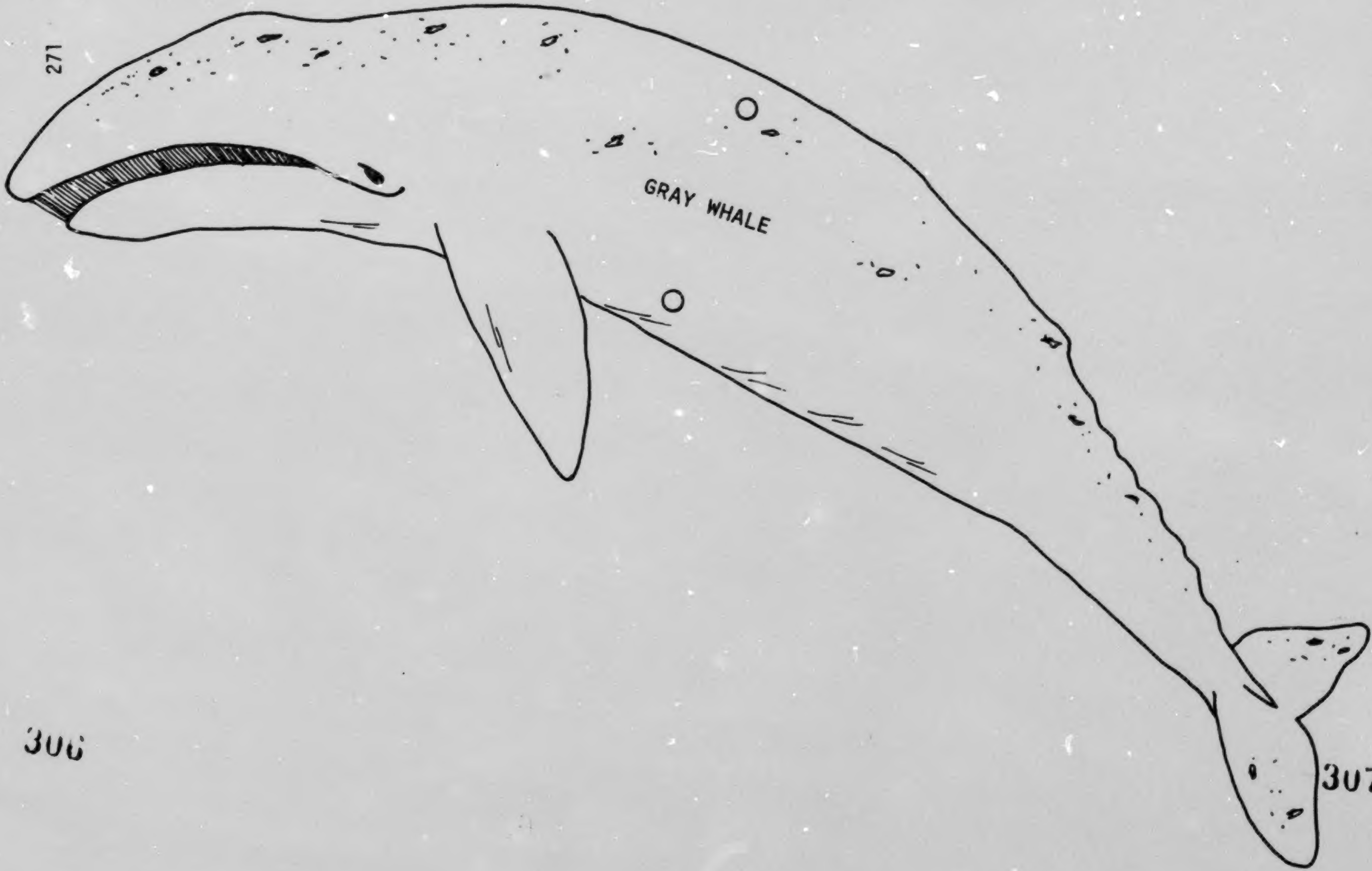
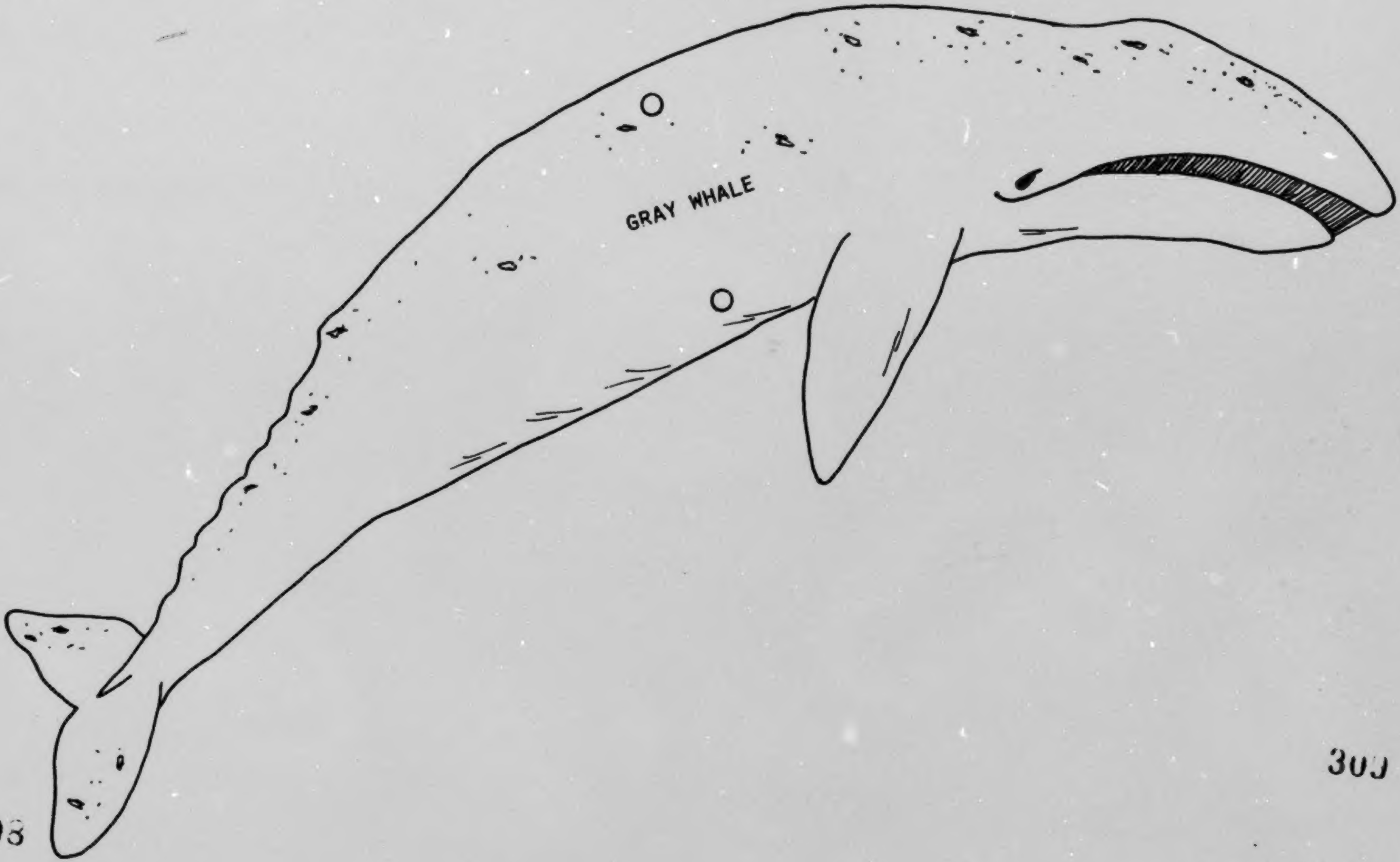
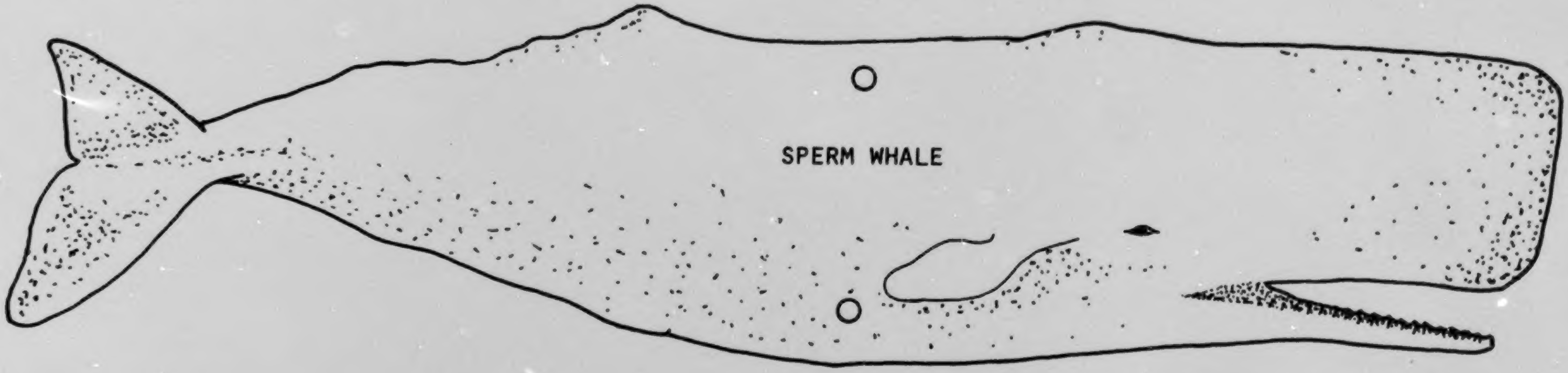
(eaten by toothed whales)

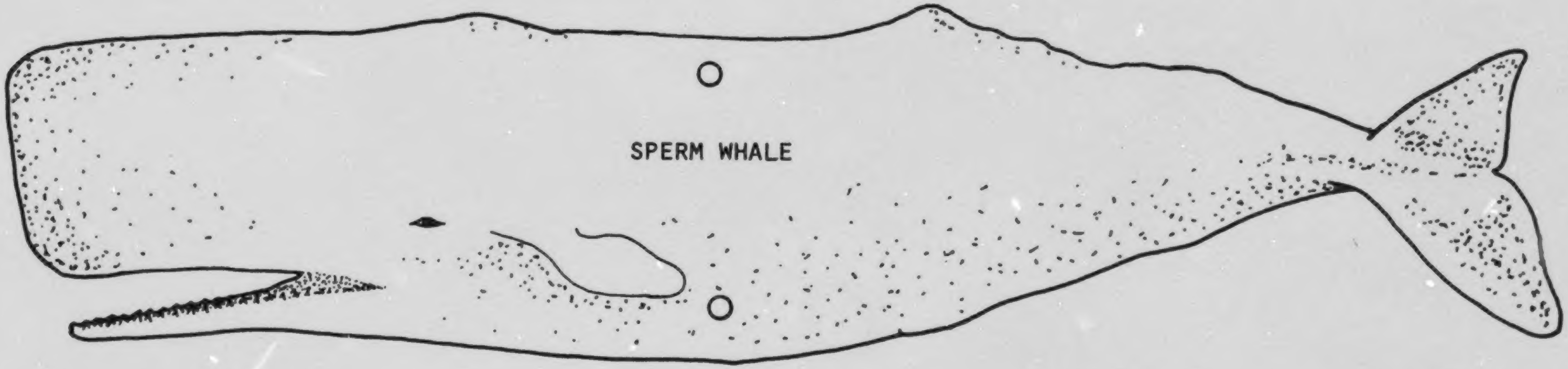

SQUID
(eaten by toothed whales)


SABLEFISH
(eaten by toothed whales)


GRAY WHALE


GRAY WHALE


SPERM WHALE


SPERM WHALE

TEACHER BACKGROUND - Who's for Dinner?

"Who's for Dinner"? is a role playing game designed to help your students understand the food chain concept. Your students will play the roles of shrimp, herring and salmon. The first link in the food chain will be plankton (represented by popcorn) spread over the game area. The shrimp eat the plankton, the herring eat the shrimp and are, in turn, eaten by the salmon. The object of the game is for each animal to get something to eat without being eaten during the timed course of the game.

"Who's for Dinner"? is a poor model of nature because of the small population sizes. Natural populations are usually able to withstand the loss of some of their individuals. In our populations, the survival of any of each kind of animal will be considered a success. The community is "balanced" and will survive.

At least 10 students are needed for best results.

Directions:

The object for each student is to survive as an animal in a food chain by getting enough to eat while avoiding being eaten.

Materials:

4-5 liters of popped corn
clipboard and paper for results
marking pen
kitchen timer with bell
roll of 1" masking tape
1 plastic sandwich bag for each student
2 colored, 8½ x 11, pieces of paper for each student (see next section) or 1 sash about 20cm x 100cm for each student.
2 safety pins for each student

Before you are ready to being the role playing, you will need to prepare the following:

stomachs: The plastic sandwich bags will be animal stomachs. Place a strip of masking tape 4cm from the bottom running across the bottom edge.

name tags: The colored paper will serve to identify the animals. You will need three colors: one for the shrimp, one for the herring, and the third for the salmon. Have enough of each color to allow 3/4 of the group to be shrimp, 1/3 to be herring, and 1/3 to be salmon. The fact that you have a surplus of shrimp tags will allow you to change population numbers as the game progresses. You will pin a piece of the colored paper on the front and on the back of each student.

Introduction:

Briefly review food chains. You might ask your students if they know what shrimp eat and what eats shrimp. They may respond "shrimp eat plankton and fish eat shrimp". Diagram the relationship they describe and introduce it as a food chain.

plankton ⟶ shrimp ⟶ fish

Ask your students if they can think of other food chains, including a food chain that contains man.

How to Play:

1. Outline the boundaries of the game area. An area about 15 meters square is adequate. A grass area is best, but a gymnasium, a parking lot etc. will work. Outdoors missed popcorn plankton will be eaten by birds or other small animals.

2. Spread about 3/4 of the plankton (popcorn) over the area. Tell your class you are spreading out the plankton that the shrimp will eat.

3. Hand out a plastic bag stomach and two shrimp name tags to each person in 1/3 of your group. Tell your students to put their food (popcorn) into their stomachs when the game begins.

4. Hand out a bag and two herring name tags to each person in a second 1/3 of the group, and bags and two salmon name tags to the people in the last 1/3. When the game starts herring will try to capture (tag) shrimp and and salmon will try to capture (tag) herring. When a herring captures a shrimp, the shrimp's stomach contents are transferred to the stomach of the herring. When the salmon captures a herring, he takes the herring's whole stomach. Note that salmon do not eat shrimp in this game.

5. State the challenge. Set the timer for five minutes and say "Go!" The first game usually lasts only a few seconds with one of two things happening. The shrimp are gobbled up before they have a chance to forage, or the herring are gobbled up and the shrimp continue to eat popcorn and get fat.

6. Analysis. How many animals survive? For a shrimp to survive, popcorn must fill the stomach bag to the bottom of the tape (4 cm). For a herring or a salmon to survive, popcorn must fill the stomach bag to the top of the tape (6½ cm). If at least one of each kind of animal survives, you have an on-going food chain. Return the popcorn to the activity area after each game.

7. Encore: Learning by making rule variations. Ask for suggestions on rule changes that might result in more of a balance after the five minute "day". Usually one rule is changed for each replay. When you have settled on your new rules, play again. Suggest these changes if your students can't offer any:
   a. Change the number of shrimp and/or herring and/or salmon.
   b. Let each shrimp come back as another shrimp once after being captured and transferring stomach contents.
   c. Provide a "safety zone" for shrimp and/or herring where they can be safe.
   d. Timed releases. Let shrimp go first to forage unmolested. One minute later release the herring, and later the salmon.
   e. Spread out more popcorn.

To reduce discontent over who will be which organism, draw markers from a hat to assign roles for replays.

AFTERWORD.............

Analyze the results of each game. How many shrimp got a full stomach? How many herring? How many salmon? Compare game results after each rule change and comment on how the game "balance" compares with the balance in the real world. In nature, there are more plants than plant eaters and more plant eaters than animal eaters.

Here are some questions to consider back in the classroom:

1. What would happen if there were only half as many popcorn plankton?
2. If there were no herring, what would happen to the plankton population? The shrimp population? The salmon population?
3. So salmon need plants to survive? Explain!
4. Can you describe some food chains that you are part of?
5. Are there any plants or animals that are not part of any food chains?
6. Which variation provided the most realistic conditions?

Adapted from "Food Chain Game" by Outdoor Biology Instructional Strategies (OBIS), Lawrence Hall Of Science, University of California, Berkeley, California.

TEACHER BACKGROUND - Plankton - A Case Study and In Search of the Wild Plankton and Magnifying the Problem.

The giant California gray whale sustains its life by feeding on vast quantities of zooplankton. The following three activities will provide your students with a glimpse into the planktonic world. Although the copepod crustaceans eaten by gray whales are, in fact, easily visible to the unaided eye, your students will be capturing and observing the more numerous, smaller planktonic forms. These activities provide additional reinforcement of the concepts surrounding food chains.

"Plankton - A Case Study" provides your students with a look at the factors which contribute to the abundance of plankton found in a particular location, the Puget Sound. This activity is based on an article by John Eddy II entitled "Plankton: the basis of life in the sea" found in the September/October 1977 issue of The Seattle Aquarium Journal (Vol. 1, No. 1). This activity is best completed by individual students as a homework or in-class assignment. The information presented in "Plankton - A Case Study" provides the background for the subsequent two activities. Prior to embarking on "In Search of the Wild Plankton" and "Magnifying the Problem" provide time for a discussion during which you elicit answers for the "Analysis and Interpretation" questions.

"In Search of the Wild Plankton" outlines the construction of a simple plankton net. Plankton may be obtained from ponds, lakes, streams, bays, sounds, oceans, aquaria, etc. This activity provides "hands on" work with plankton. Although plankton nets are available for purchase from scientific supply houses, there is much to recommend home construction as opposed to purchase. In addition to being economically sound, this activity provides your students with some practice in direction following. Ideally, you will be able to organize a class field trip to sample plankton. Alternatively, you may let your students sample plankton on their own and later bring their samples to class. Field trips mean extra work and preparation for you. The return in student enthusiasm and learning, however, more than pays for the extra work. You can lead a successful field trip by following the instructions found earlier in this text .

Several sampling methods will provide you with adequate plankton. Pulling the net behind a slowly moving boat (1 - 2 knots) is a standard method for collecting plankton. Lower the net vertically into the water until the bottle is full of water. Then pull until the net is extended. Commence towing. Record the starting time and location so that the distance towed can be recorded. For surface - depth sampling, tie a weight to a separate line and fasten the line to the front swivel. Bring in the net at the end of the tow and allow it to hang for a few minutes. Wash all of the plankton from the sides of the net into the bottle by running water from the outside of the net. Bacause stocking material stretches, changes in towing speed change the mesh size. Slow speeds will have the smallest mesh size. Because of this, your nets will tend to capture more of the smaller phytoplankton at slow speeds.

If a boat is not available, good results can be obtained by towing the net as you walk along on a dock. You can also throw the net from a bridge or pier into a fast tidal current. While these techniques make it more difficult to determine how much water has passed through the net, they will give good supplies of plankton for observation. Your students will greatly profit from performing the actual collecting.

"In Search of The Wild Plankton" is best accomplished in pairs although you may wish to have each student construct her own net. Have your students provide the stockings, coat hangers, and bottles. Provide a completed plankton net as a construction guide. Circulate through the room as your students make their nets. Provide any aid and reassurance that may be required to make this a positive experience for your students.

After sampling is completed, the plankton captured may be viewed with a conventional microscope, hand lens, or the water lens microscope constructed in "Magnifying the Problem". Live plankton are preferred for observation. If there will be a delay of more than one or two hours between sampling and observing, preserve the sample by adding 5% formalin.

"Magnifying the Problem" provides your students with the opportunity to make a water lens microscope. Constructed from simple materials, the microscope will enable your students to examine the plankton samples they have collected with their plankton nets. The curiosity generated in this activity can be profitably turned toward the use of the conventional microscope and the different world that it opens.

"Magnifying the Problem" is best accomplished in pairs or small groups. Your students can provide most of the materials needed. Small pieces of window glass can often be obtained from your maintenance department when they replace broken windows (6" X 12" is ideal). As a precaution against cuts, "break" (lightly sand) the glass edges with wet/dry sandpaper wetted with a light oil. Introduce the activity with a brief history of the microscope and provide a model water lens microscope for your students to use as a construction aid. During the construction and use phases, circulate through the class and provide any aid that may be required.

While any one of these activities may stand on its own, the three complement each other and involve your students in the process best when used together. Net construction and microscope construction are best completed before the plankton are sampled. This sequence maximizes the opportunity to view living plankton. The drawings provided in the text are not intended to serve as definitive identification keys. At this point, it seems that identification should be limited to distinguishing phytoplankton from zooplankton. If you have students who are interested in specific identification refer them to the following:

Cupp, E. E., 1943. Marine Plankton Diatoms of the West Coast of North America. Berkeley. Calif.: University of California Press, (OP).

Hardy, A. H., 1961. The Open Sea: Its Natural History: Part I The World of Plankton, Houghton-Mifflin Co.: Boston.

Newell, G. E., and R. C. Newell. 1963. Marine Plankton - A Practical Guide. Hutchinson Education. London. 244 pages.

Smith, Deboyd L. 1977. A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae. Kendall/Hunt Publishing Company; Dubuque, Iowa. 161 pages.

Smith, R. I., and Carlton, J. T. 1975. Light's Manual, Intertidal Invertebrates of the Central California Coast. U. Calif. Press.

Wimpenny, R. S. 1966. The Plankton of the Sea. N.Y.: American Elsevier Pub. Co.

KEY

Plankton - A Case Study

1. The two types of plankton mentioned are phytoplankton (plant plankton) and zooplankton (animal plankton).
2. Phytoplankton require sunlight and nutrients for survival.
3. One would expect to find more fish in areas of high planktometer readings because the fish depend either directly or indirectly upon the plankton for their food.
4. Freshwater runoff adds nutrients that the streams and rivers have eroded from the land. These nutrients benefit the plankton populations.
5. The inflow of deep ocean waters helps replenish the nutrients the growing phytoplankton strip from the surface water. The water flowing out at the surface and in at depth make Puget Sound a nutrient trap.
6. a. While the answer depends upon the care with which the experiment is performed, generally the colored, salty water will form a distinct layer at the bottom of the jar.
   b. The salty, colored water is more dense than the clear freshwater. This is evidenced by the fact that the salty, colored water sank when slowly added to the clear freshwater.
7. The third path which brings nutrients to the plankton is the movement of water in tidal currents. The tidal currents coupled with deep, narrow basins, carry nutrient-rich deep water to the surface.
8. Since the zooplankton eat the phytoplankton, the phytoplankton must increase first to provide food to enable the zooplankton to increase. The population growth curves for the phytoplankton and the zooplankton are very similar in shape but they are slightly out of phase.
9. A completed food chain follows:

phytoplankton ⟶ zooplankton ⟶ herring ⟶ squid ⟶ orca

10. The four major paths which bring nutrients to the surface waters of Puget Sound are:
    a. freshwater runoff
    b. outflow of surface waters and inflow of deep Pacific Ocean waters
    c. tidal currents
    d. wind mixing
11. Plankton are the basis of all life in the sea in the sense that all other animals depend either directly or indirectly on plankton for the nutrients they require to live. This answer reflects the central concept of this activity: All of the life in the sea is interrelated through the plankton.

In Search of The Wild Plankton

There are no specific questions for this activity. The material is covered in "Magnifying the Problem".

Magnifying the Problem

1. The answer depends upon experimental results.
2. In general, one would expect to find more phytoplankton than zooplankton. Since the phytoplankton provide food for the zooplankton, they must be more numerous. While phytopoankton are more numerous in the seas, it does not necessarily follow that our plankton nets capture a representative proportion of phytoplankton and zooplankton. Because of their small size, phytoplankton are often under-sampled.
3. a., b., c. Answers depend upon experimental results.
4. Answers will vary with the creativity of your class. One improvement of the microscope might be replacing the drop of water with a ground glass lens. Your students will have other specific suggestions after their construction and use experiences.
5. As noted in question 11 above, plankton are the basis of all life in the sea in the sense that all other animals depend either directly or indirectly on plankton for the nutrients required for life. Emphasize this point as you summarize these activities.

KEY WORDS

Plankton - A Case Study

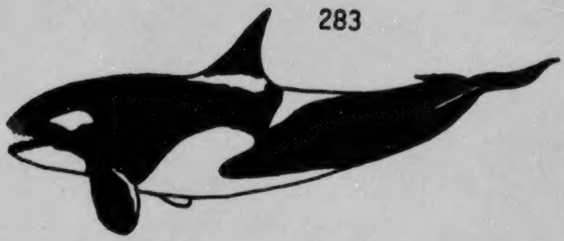
alternate
basin
blooms
dense
diet
eroded
exhales
food chain
inhales
microscopic
nutrients
phytoplankton
plankton
populations
precipitation
Puget Sound
ratio
runoff
stripped
tidal currents
tides
volume
watershed
zooplankton

In Search of the Wild Plankton

alternatively
bridle
conventional
diameter
dowel
hand lens
net
phytoplankton
plankton
zooplankton

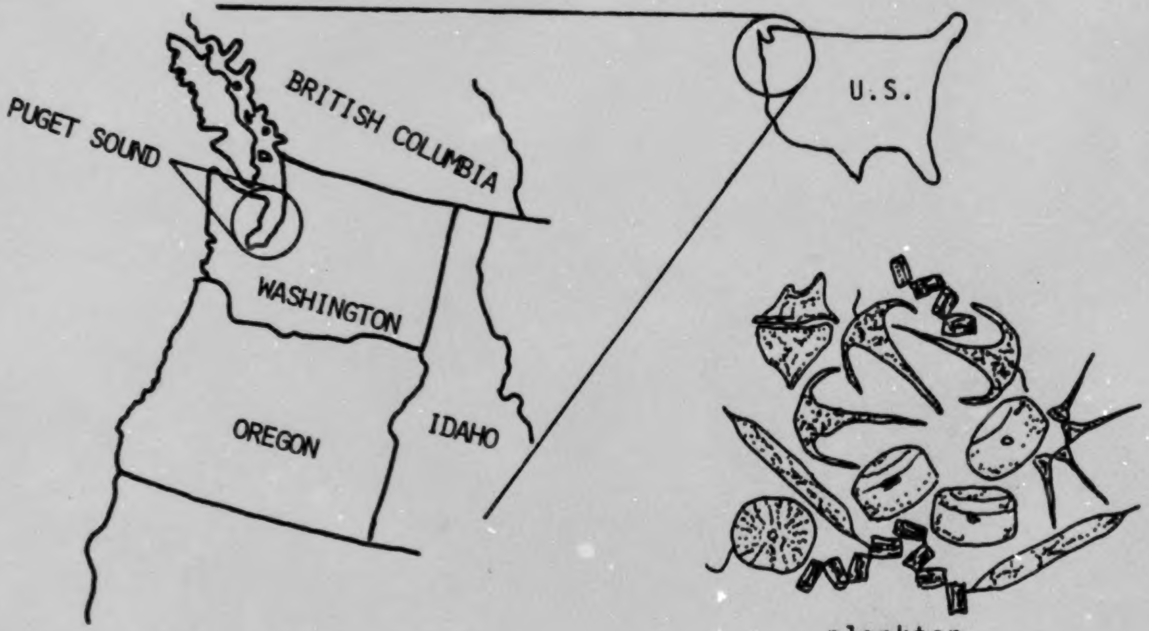
Magnifying the Problem

basis
common
crude
dull
estimate
geometric
microscope
observe
pane
phytoplankton
plankter
plankton
tin snips
transfer
water lens microscope
zooplankton



PLANKTON - A Case Study

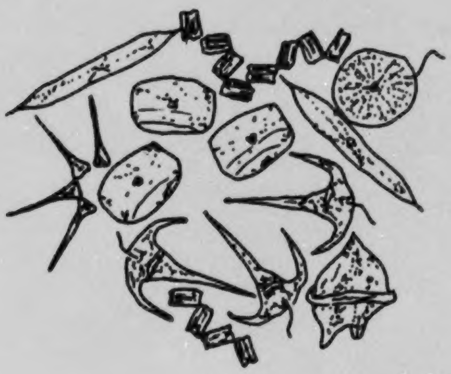
Washington's Puget Sound is the home for a remarkable assortment of marine life. Is there a single reason which explains the abundance of life? If you must choose only one reason it would be the presence of tremendous populations of plankton. Plankton is the basis of marine life the world over. In the Puget Sound conditions for plankton are ideal.


BRITISH COLUMBIA
PUGET SOUND
WASHINGTON
OREGON
IDAHO
U.S.

plankton

Most plankton are microscopic plant and animal organisms that drift along at the mercy of currents.

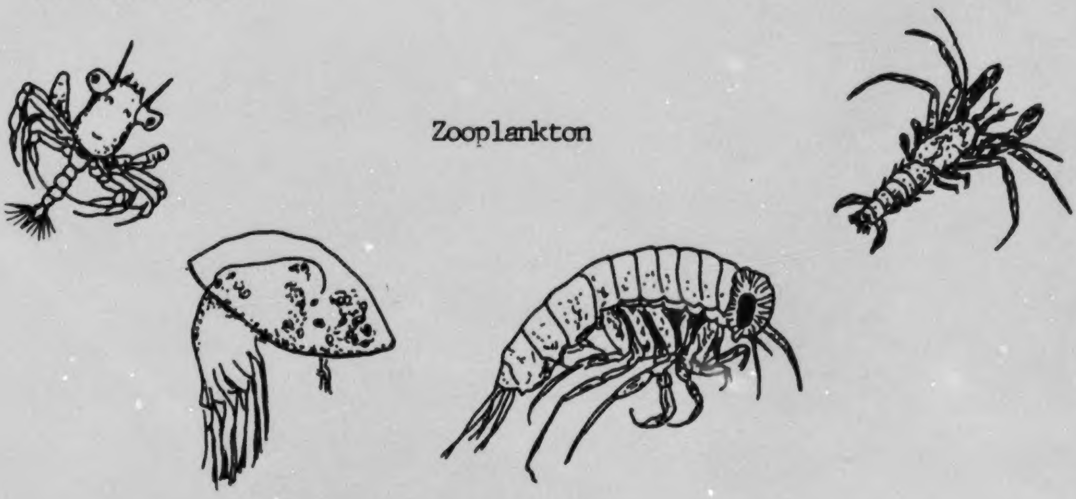
Plant plankton are called phytoplankton. Like land plants, the tiny phytoplankton need sunlight and nutrients to survive.



Phytoplankton

.001MM TO 0.1MM

Animal plankton are called zooplankton. For the most part, they require phytoplankton for food. Since sunlight does not penetrate very deeply into the water, the phytoplankton must live near the surface. The zooplankton depend upon the phytoplankton. The phytoplankton depend upon sunlight and nutrients. The Puget Sound is a storehouse of nutrients.



Zooplankton

0.5MM TO 20MM

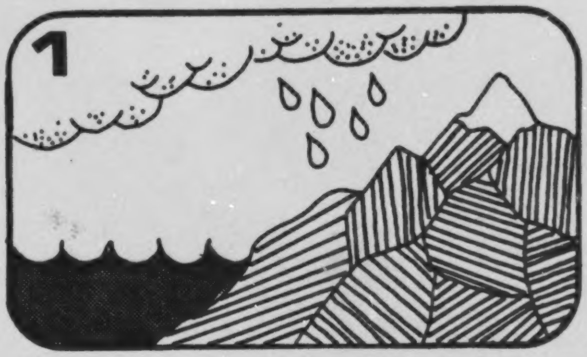
1. What are the two types of plankton?

2. What do phytoplankton require for survival?

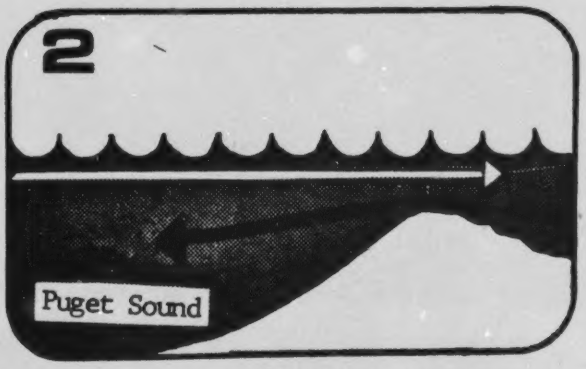
Phytoplankton remove the nutrients from the near-surface waters. These nutrients enable the phytoplankton to grow and live. As the plankton eat, are eaten, and die, they slowly sink. As they sink, their nutrients are carried to deeper waters. Nutrients in the dark deep waters are of little use to plankton. Over most of the world's oceans, the nutrients never return to the surface waters. Without these nutrients the waters have little life. In the Puget Sound nutrients are being constantly returned to the sunlit surface waters.

3. As skipper of the Margaret D., you are searching for albacore tuna. You are using your own invention, the planktometer. The planktometer counts the number of plankton in the water. Would you expect to find more fish in areas of high planktometer readings or low readings? Why?

In the Puget Sound, four major paths bring nutrients to the surface. As shown in figure 1, one major path is through freshwater runoff. Rain and snow fall on the land surrounding the Sound. This area is called a watershed. The water from the precipitation (rain and snow) eventually flows into the Puget Sound. The watershed drains nearly 11,000 square miles of land area into Puget Sound's 1000 square miles of surface area. Compare this 11 to 1 ratio with the Baltic Sea's 4 to 1 or the Great lake's 2 to 1 ratio. If Puget Sound were drained completely, it would take less than four years to refill it with freshwater runoff from its watershed! Other bodies of water might take over a hundred years. All of this freshwater flowing into the Sound carries nutrients that the streams and rivers have eroded from the land.



4. How does freshwater runoff add nutrients for Puget Sound plankton?



A second source of nutrients in Puget Sound is the nutrient-rich deep waters of the Pacific Ocean. Freshwater is less dense than saltwater This means that freshwater will float on top of saltwater. Freshwater runoff from rivers and streams mixes with the Sound's surface waters.

These mixed waters are lighter than the layers of saltier water below. This lighter surface layer flows out of Puget Sound and into the Pacific Ocean. This outflowing water is constantly replaced by the inflow of nutrient-rich deeper waters from the Pacific Ocean. In the Puget Sound, water flows out at the surface and in at depth. In figure 2 the outflowing water is shown as a white arrow. The inflowing water is shown as a black arrow. This flow pattern lets Puget Sound trap nutriets. Plankton in the Sound strip nutrients from the surface water flowing out. As oceanic plankton die, they pass their nutrients to deeper oceanic waters. These nutrient rich deep oceanic waters are then sucked into the Sound. The plankton in the Sound use these oceanic nutrients for growth.

5. How does the inflow of deep ocean waters help explain the large numbers of plankton in Puget Sound?

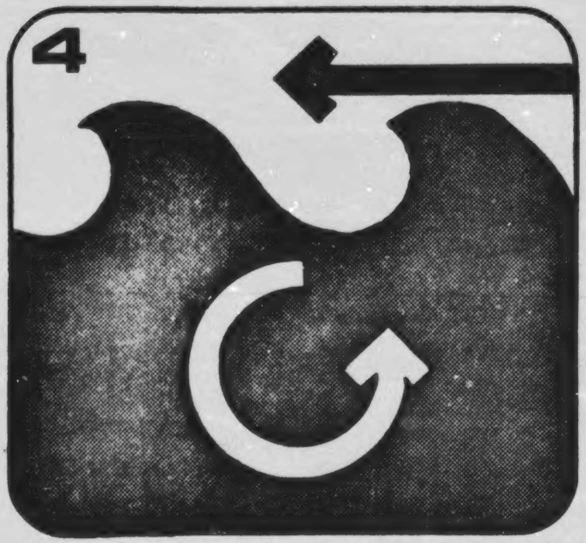
6. Try the following experiment. Obtain two beakers or jars of tap water. Add three drops of food coloring and three tablespoons of salt to one of the jars. Stir the water until the salt dissolves. Now slowly pour the colored, salty water down the inside wall of the other jar.

    a. What happens?

    b. Which water is more dense? How can you tell?

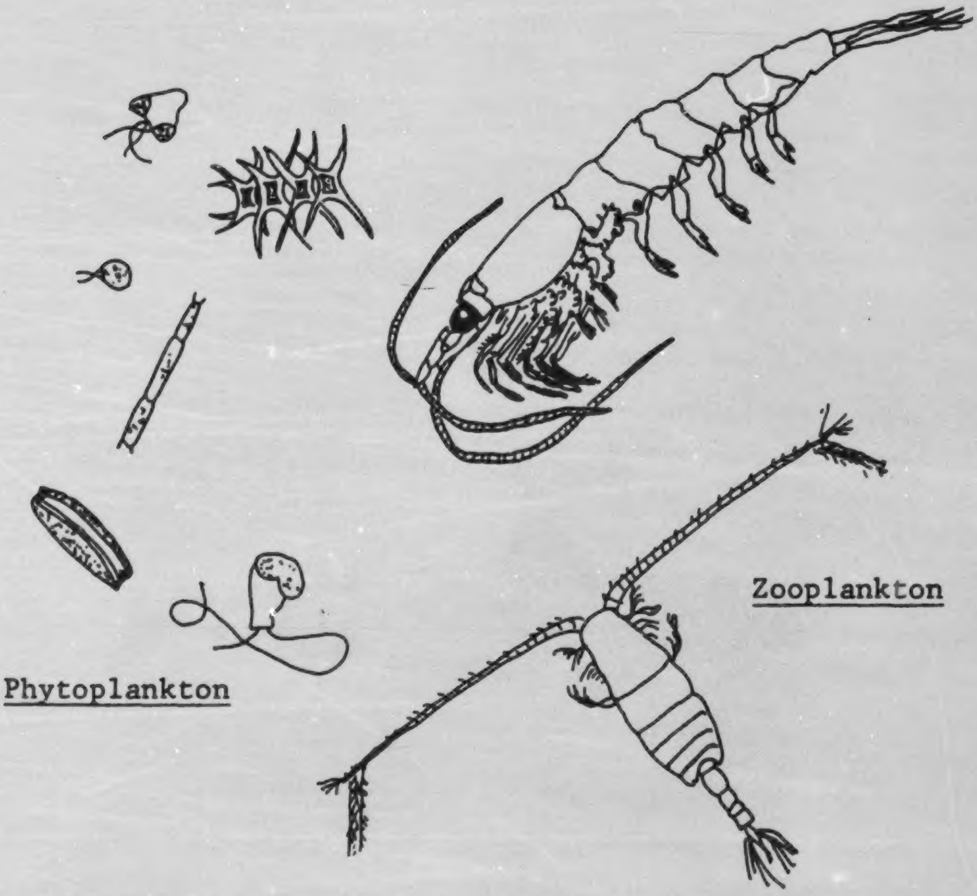
The third path bringing nutrients to the plankton is driven by tidal currents. In addition to the movement of water due to different densities, the tides also move Puget Sound waters. Puget Sound exhales and inhales a tremendous volume of water twice each day. The arrows in figure 3 show water moving into and out of the Sound. These tides cause tidal currents. As the currents rush from deep basins up through narrow, shallow passages, nutrient-rich deep water is carried to the surface.

7. What is the third path which brings nutrients to the plankton?

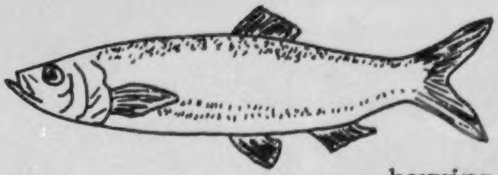


The fourth path carrying nutrients to the surface is wind mixing. In early fall, wind storms alternate with warm sunny weather. The wind produces waves. The waves cause enough mixing to bring nutrients to the surface. Figure 4 shows how the wind (black arrow) causes mixing (white arrow) in the water. Water temperatures are warm and the days are long. The phytoplankton begin reproducing by dividing furiously until the population literally explodes. The zooplankton suddenly have lots to eat. Their population also explodes. These population explosions are called blooms. The blooms continue until the phytoplankton have stripped the nutrients from the surface waters. With no nutrients, most of the phytoplankton die. With no phytoplankton many zooplankton also die.

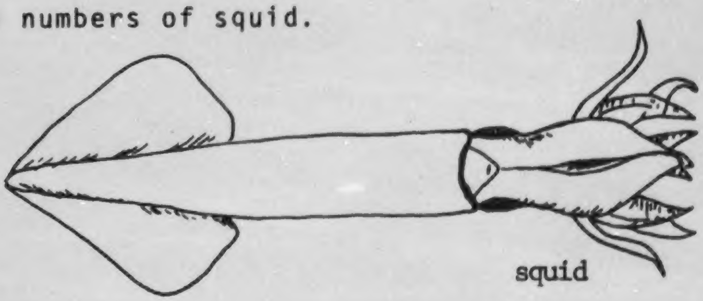
8. Scientists have noticed that the increase in zooplankton occurs after the increase in phytoplankton. How does the diet of these animals explain the observation made by scientists?



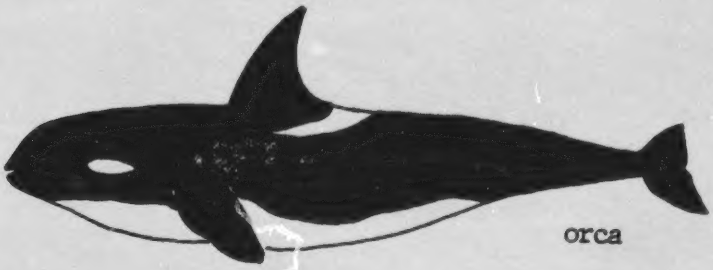
How does this tremendous population of microscopic plants and animals affect the lives of those animals we can see? Herring are slender, silvery fish. Herring eat plankton. Large numbers of plankton mean large numbers of herring.



Squid eat herring. Large numbers of herring mean large numbers of squid.



Squid are eaten by orcas (killer whales). Large numbers of squid mean large numbers of orcas.



So, the most impressive of animals, the orca, depends upon the microscopic plankton. All life is tied together through these feeding relationships. Plankton are the basis of life in the sea.

9. The description of who eats whom is called a food chain. Food chains are easy to draw. Start with the phytoplankton. Connect the eaten with the eater. Do this by drawing an arrow pointing from the eaten to the eater. (For example: phytoplankton ⟶ zooplankton). The arrows show where the nutrients go. In the space below make a food chain from phytoplankton to orca.

10. What four paths bring nutrients to the surface waters of Puget Sound?

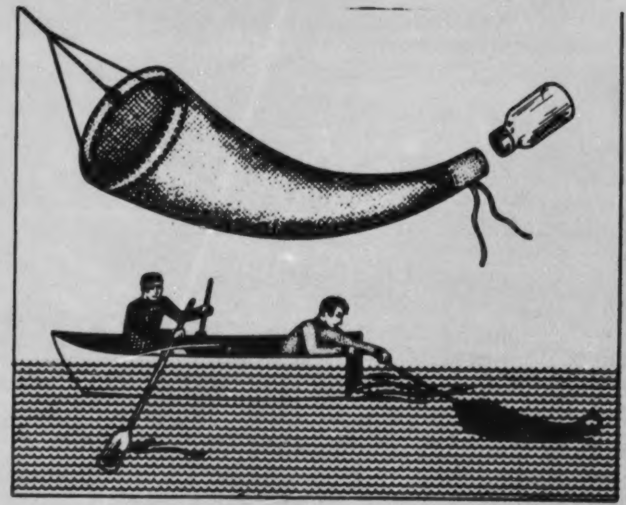
    a.

    b.

    c.

    d.

11. What does it mean when we say that plankton are the basis of all life in the sea?



IN SEARCH OF THE WILD PLANKTON

"Your assignment, should you choose to accept, is to capture tiny plants and animals now drifing in water."

Plankton are drifting plants and animals. Most are microscopic. They drift in both fresh and salt water. In the oceans plankton are the basis of life. Plankton come in many different sizes and shapes. The strange and beautiful shapes help plankton float in the sunlight-filled surface waters. The plant plankton, phytoplankton require sunlight to survive. The animal plankton, zooplankton are also found near the surface.

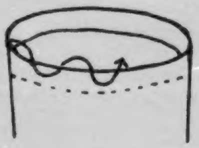
In the following activity you will make a net to help you capture these tiny creatures.

Materials:

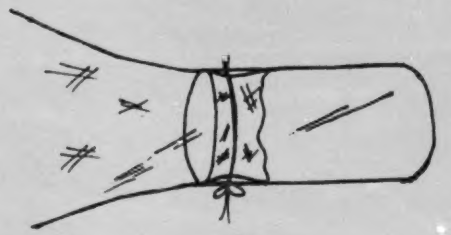
wire (coat hanger wire works well)
tape (plastic electrical works well)
nylon stocking or single leg cut from panty hose.
needle and thread (heavy)
small bottle (preferably with neck indentation)
string
scissors

Procedure:

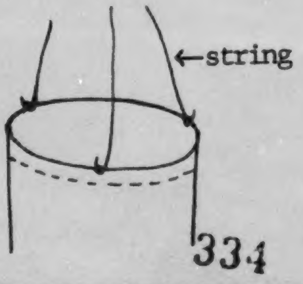
1. Obtain a piece of wire and a nylon stocking. Bend the wire into a circle about the size of the top of the stocking. (Hint: If you have trouble forming a circle, bend your wire around a gallon paint can or similar container).
2. Fasten the loose ends together with tape.
3. "Roll" the mouth of the stocking several times around the wire ring.
4. Sew the stocking to the wire using a needle and heavy thread.



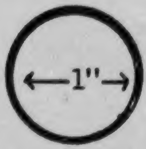
5. Obtain a small bottle. Cut off the foot of the stocking. Use string to tie the bottle in the end of the stocking.



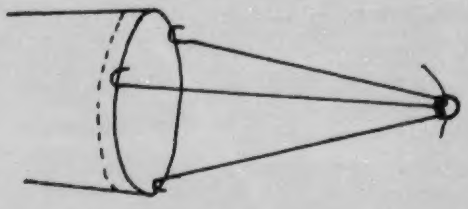
6. Obtain three pieces of string about 18 inches long. These will form the bridle for towing your net. Fasten them at equal intervals around your ring.



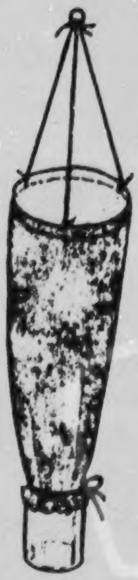
7. Obtain a piece of wire about 6 inches long. Wrap the wire around a broom handle or dowel to form a 1 inch diameter circle.



8. Tie the three loose ends of your bridle strings to the 1 inch ring.



9. Your finished plankton net should look something like the following picture



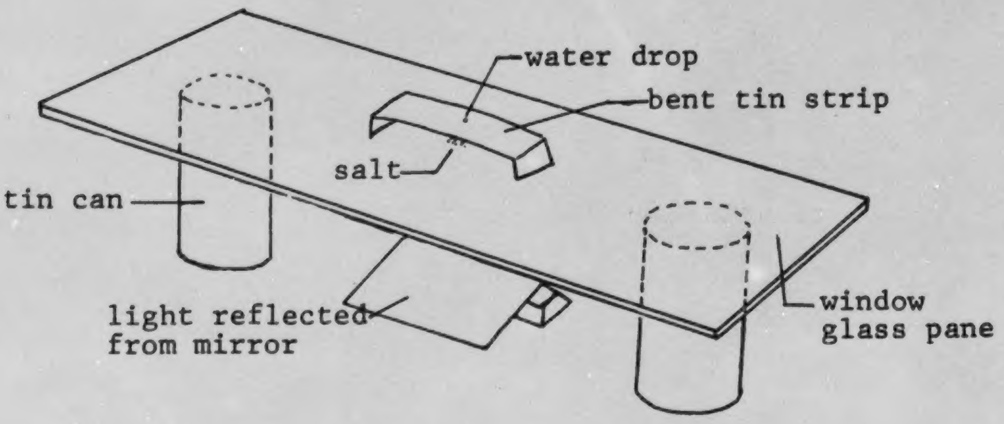
10. To catch plankton. Tie a length of string to your bridle ring. Pull the net through the water The plankton will collect in the bottle. You can remove the bottle by untying the string.

11. Observe the plankton you capture by using the water drop microscope you will construct in the next activity. Alternatively you may use a conventional microscope or hand lens.

MAGNIFYING THE PROBLEM

So now you have a problem......You've captured your plankton, how are you going to observe them? Why not make a microscope? In the following exercise you will make a water lens microscope. This microscope seems like a crude tool. It may help to know that early biologists made many very important discoveries using microscopes that were little better than the one you will make.

WATER LENS MICROSCOPE


water drop
bent tin strip
salt
tin can
light reflected from mirror
window glass pane

Materials:

- tin snips
- sheet tin
- file
- adhesive tape

rulers

blocks of wood

nail

hammer

pliers

grease or cooking oil

pencil

water

pane of window glass

tin cans, two of same size

mirror

pepper, salt or sugar

water sampler

clear plastic ruler, mm

paper

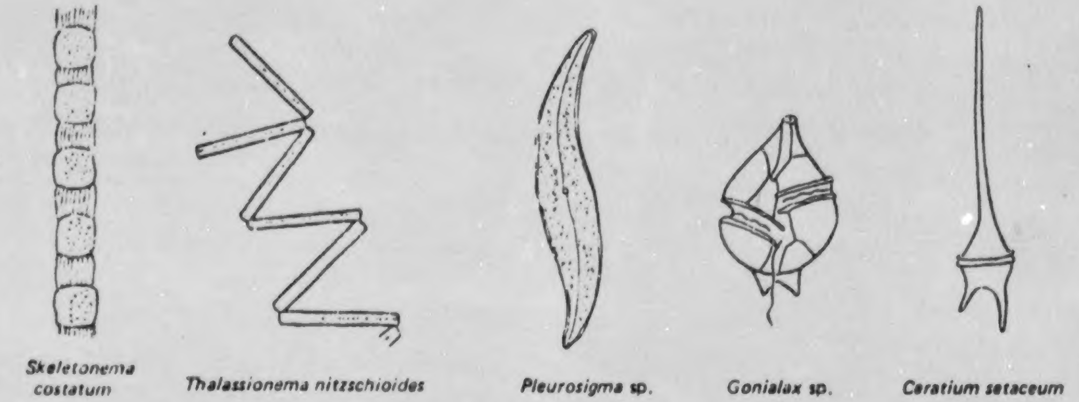
eye dropper

plankton sample

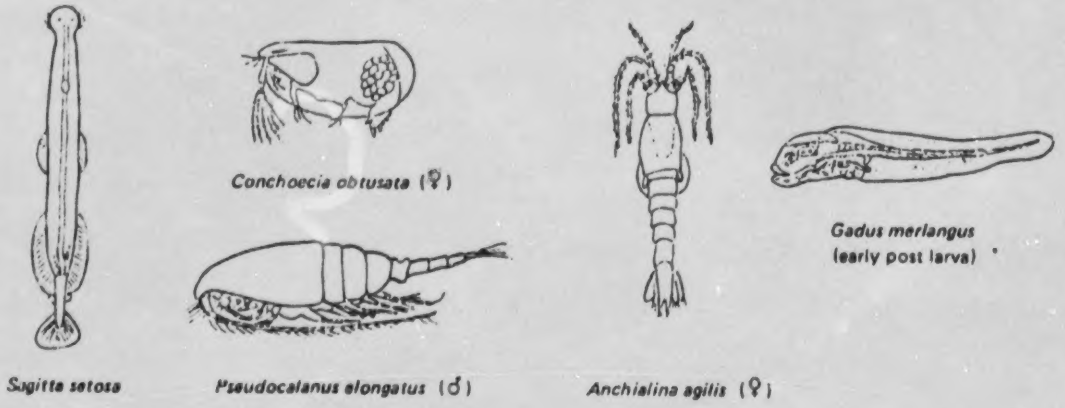
Procedure:

1. Obtain a pair of tin snips. Cut a strip from sheet tin or a tin can. This tin strip should be about one inch wide and four inches long. Be careful not to cut yourself on the sharp edges of the tin.
2. After the strip is cut, dull the edges with a file or cover the edges with adhesive tape.
3. Mark the exact center of the tin strip.
4. Place the strip on a piece of wood and drive a medium size nail through the center. Do not use a nail that will make a hole more than one-sixteenth inch in diameter.
5. Remove the nail and the piece of wood.
6. Bend the ends of the strip downward so that the strip will stand.
7. Rub a little grease or oil around the hole in the strip.
8. Stand the strip on its two ends.
9. Dip a pencil in water and carefully remove it.
10. Transfer a drop of water from the end of the pencil to the hole so that a drop hangs in the hole forming a lens.
11. Place a small pane of window glass on the tops of two tin cans of the same size. (Careful with the glass!)
12. Place the tin strip carefully on the center of the glass.
13. Beneath the glass prop a flat mirror so that light is reflected upward through the glass and the water lens.

14. Beneath the lens, place a few grains of pepper, salt or sugar and look down through the lens.
15. Focus the lens by gently pressing on the strip.
16. Using an eye dropper, place a drop of your plankton sample beneath the lens.
17. Sketch the organisms as you see them. The drawings below will help you identify your plankton.


Skeletonema costatum
Thalassionema nitzschioides
Pleurosigma sp.
Gonialax sp.
Ceratium setaceum

Phytoplankton


Conchoecia obtusata (♀)
Gadus merlangus (early post larva)
Sagitta setosa
Pseudocalanus elongatus (♂)
Anchialina agilis (♀)

Zooplankton

18. Place a clear plastic ruler beneath the lens.

Count the number of millimeter divisions seen through the lens. Record the number: ___________mm divisions.

19. Answer the following questions.

Analysis and Interpretation:

1. Look at the plankton drawings. Notice that phytoplankton tend to have geometric shapes (cubes, discs, etc.). Does your sample contain more phytoplankton than zooplankton?

2. In general, would you expect to find more zooplankton than phytoplankton? Please explain your answer.

3. Estimate the size of the most common plankton. You can do this easily. Follow these three steps.

   a. How many millimeter divisions could you see?

   (Step 18) _____________mm.

   b. How many of the most common plankton would fit across your field of view?

   _____________plankton.

   c. To find the size of one plankton, divide the number of millimeters by the number of plankton.

$$\frac{\underline{\qquad}\text{ mm divisions}}{\underline{\qquad}\text{ plankton}} = \underline{\qquad}\text{ size of plankton in mm.}$$

4. What is one way in which you could improve your water lens microscope?

5. What do we mean when we say, plankton are the basis of life in the sea?

TEACHER BACKGROUND - Eschrichtius robustus Who? and July 1

"Eschrichtius robustus Who?" begins what will evolve into an in-depth look at the world of the California gray whale. The gray whale will serve as a vehicle for the investigation of many of the factors which influence life in the sea. "July 1" gives a brief glimpse of how the whale spends her summer months. The feeding discussion leads into several activities focusing on food chain dynamics. The food chain activities follow "July 1" and have separate "Teacher Background" sections. This scheme, which has a narrative section on the gray whale followed by activities suggested by occurrences in the narrative, will be utilized throughout the remainder of this guide. Use the narratives as springboards and also as unifying agents to tie the various activities together. You are likely to encounter a great deal of interest in whales and in marine mammals in general. Capitalize on this interest. You may wish to expand the narratives and activities provided in order to tailor them to your particular class. These activities can and should be enjoyable for you and for your students.

Duplicate the text pages. One set is recommended per student. This activity is best accomplished by individual students as a homework or in-class assignment. Since these activities begin an in-depth look at the California gray whale, you may wish to augment the activities with posters, films, filmstrips etc. Be judicious in your choice of materials. The activities trace the migration of the whale in a stepwise sequence. By not indicating at the on-set that the California gray whales make one of the longest migrations known to man, you preserve an element of surprise. Allow some time for a discussion of the material covered in these introductory activities and to provide answers for the text questions.

KEY

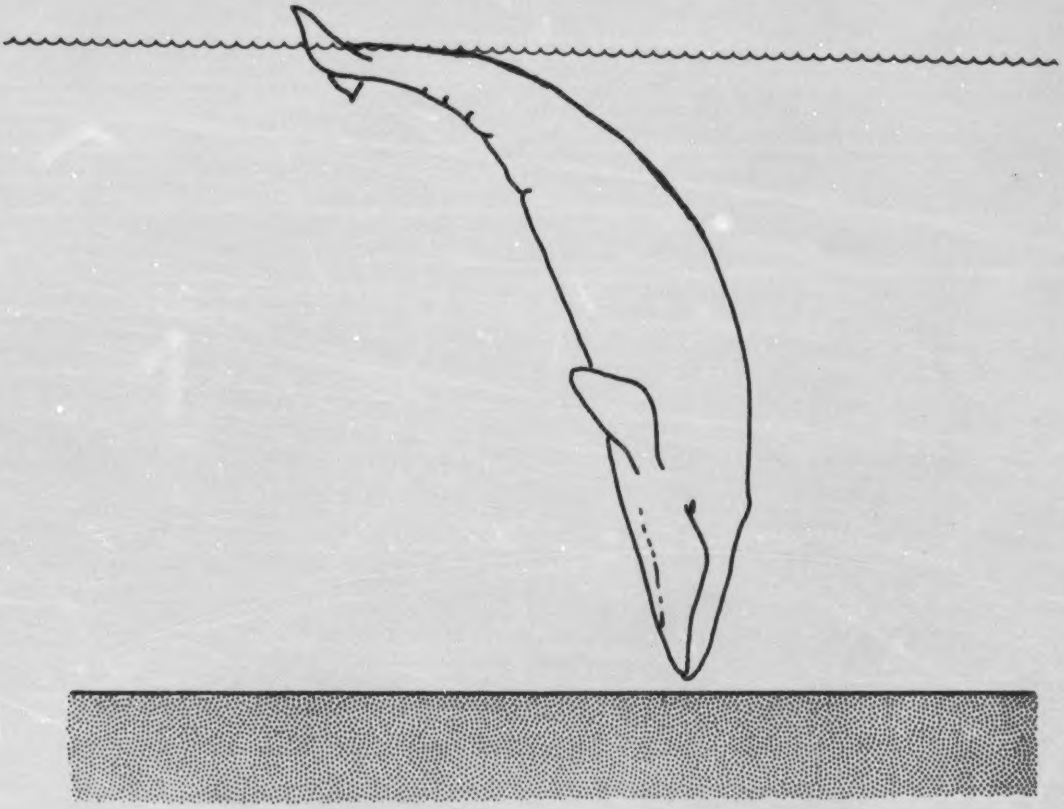
1. The two major groups of whales are:
   a. the baleen whales and,
   b. the toothed whales.
2. Baleen whales are filter feeders. A baleen whale feeds by first taking a mouthful of water (complete with plankton. She then presses her tongue against the roof of her mouth and forces the water out through her baleen plates. The planktonic animals upon which the whales feed remain behind, stuck to the "hairs" of the baleen. A swish of the tongue and swallow completes the process. The information to answer this question comes from an earlier exercise on cetaceans entitled "Return To The Sea." It is also found in the activity. "July 1."
3. a. The ancestors of all whales were land dwellers, most likely living in shallow, coastal estuaries. This question also is posed by way of review, the evolution of whales is discussed in a previous section entitled "Return To The Sea".
   b. The first whales to live entirely in the water probably spent their time [✓ *near to*] / *far away from* shore. (Circle the correct term)
   c. The less attachment a whale has with shore, the more *primitive* / [✓ *modern*] it is. (Circle the correct term)
4. a. Gray whales eat shrimp-like amphipods and other small animals.
   b. They feed on the bottom, plowing through the soft sand and mud with their snouts.
5. Blubber serves several important functions in the life of whales. The function mentioned here is insulation to reduce heat loss. Future activities will deal with the food storage and bouyancy roles of blubber.
6. a. Two populations of gray whales remain.
   b. One small group lives in the Okhotsk Sea off the Soviet coast and north of Japan. The larger group lives around the Arctic Ocean.

KEY WORDS

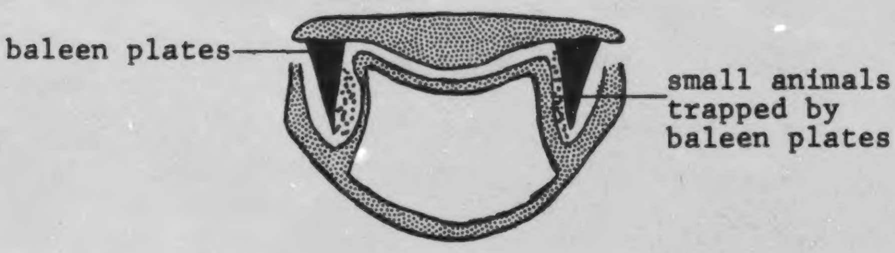
- amphipods
- ancestral
- baleen
- blowholes
- blubber
- California gray whale
- calves
- chilled
- Eschrichtius robustus
- evolved
- exterminated
- filter
- flukes
- insulation
- krill
- mussel
- populations
- prehistoric
- primitive
- shallow
- shrimp
- skeletons
- spout
- survival
- toothed whales
- tongue

ESCHRICHTIUS ROBUSTUS WHO?

Dawn finds this strange creature standing on its head in coastal waters. The first people to witness this feat called the animal "mussel eater". (Mussels are related to clams). Scientists call it Eschrichtius robustus. We call it the California gray whale.



The California gray whale is the most primitive of the living baleen whales. Baleen whales make up one of the two major groups of whales. (Using special plates, baleen whales filter their food from the water.) The second major group is the toothed whales.



1. What are the two major groups of whales?

   a.

   b.

2. How does a baleen whale feed?

The Gray whale seems to represent the ancestral group from which the two main groups evolved. The gray whale shows similarities to the toothed whales and the baleen whales. It is the only living member of a once large family.

What makes scientists think the gray whale is primitive? It has a small head with a limited filtering system. It depends upon food found near shore. Likewise, its need for harbors in which to bear its calves is a tie with its land past.

3. a. Where did the ancestors of all whales live?

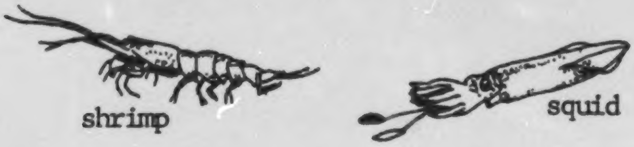
b. The first whales to live entirely in the water probably spent their time *near to / far away from* shore. (Circle the correct term).

c. The less attachment a whale has with shore, the more *primitive / modern* it is. (Circle the correct term).

The gray whale is only found in the Pacific Ocean. It seems likely that gray whales once lived in the Atlantic Ocean too. In 1937, gray whale skeletons were found in the Netherlands. Some scientists think that the Atlantic gray whales were exterminated by prehistoric whalers.

JULY 1

The long summer days cast their light on the Arctic Sea. In the shallow waters of the Bering Sea a full grown female California gray whale swims. Her head breaks the surface of the water. Her blowholes open and a rush of warm air rises. The air forms a "spout" as it condenses. The cool air rushes in and her flukes break the surface as she dives. In a few minutes she is plowing through the soft sand and mud bottom with her snout. She stirs up great clouds of small shrimp-like amphipods. She takes a mouthfull of water. Pressing her tongue against the roof of her mouth she forces the water out through her baleen plates. The amphipods and other small animals remain behind stuck to the "hairs" of the baleen. She gulps and strains another mouthful of water. She feeds for five minutes before swimming to the surface.



gray whale food

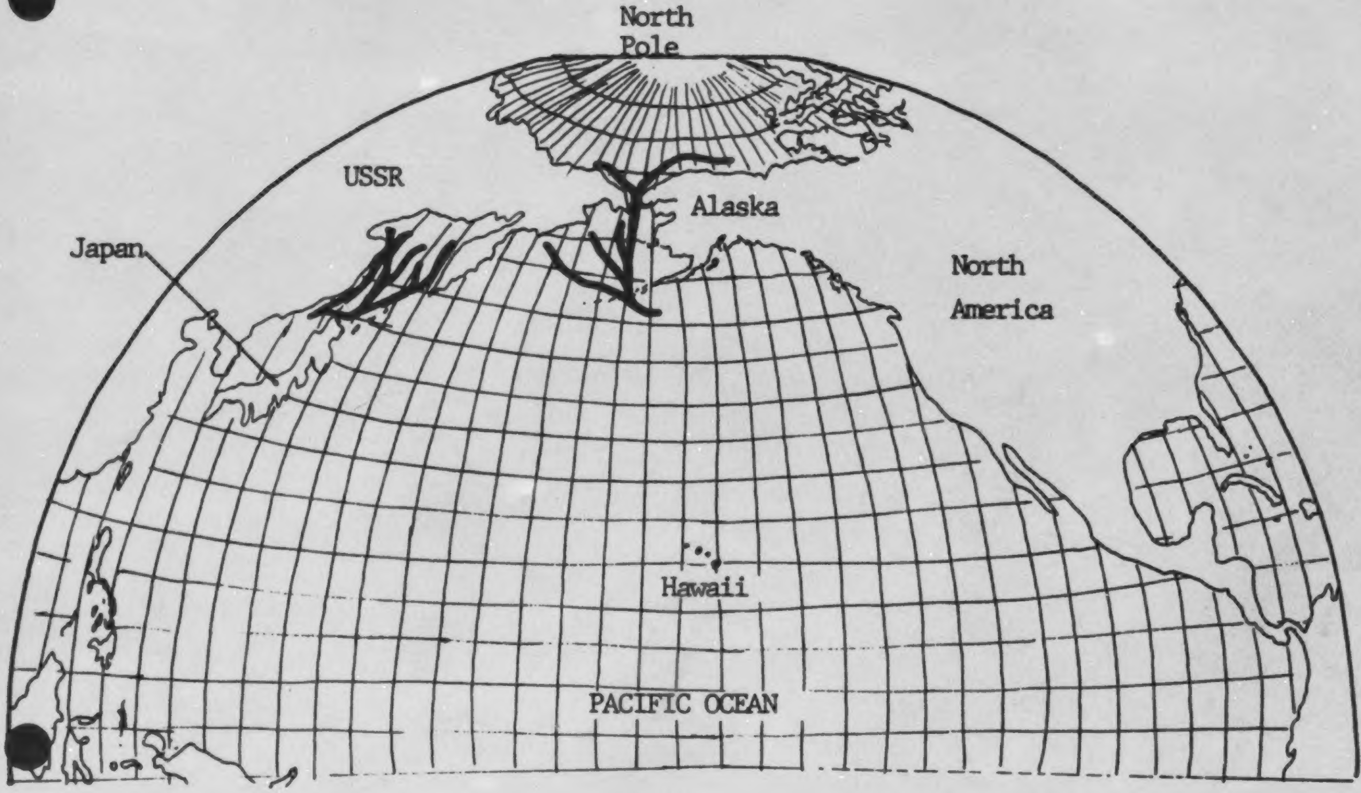
4. a. What do gray whales eat?

b. In what part of seas do they feed?

Summer life is easy. She begins to increase her layer of blubber. Blubber is a fatty layer important for the whale's survival. If you have had to swim in cold water you know how quickly you become chilled. The chilling comes from a loss of body heat. Blubber acts as insulation to reduce this heat loss. Our whale will spend the next three months feeding on these abundant food organisms known as krill.

5. How is blubber important for the whale's survival?

Today two populations of gray whales remain. A small group spends a portion of its life in the Okhotsk Sea off the Soviet coast and north of Japan. The second, and larger group, spends a portion of its life amid the ice of the Arctic Ocean. Through the next activities, you will spend a year with an Arctic Ocean California gray whale.


North Pole
USSR
Alaska
Japan
North America
Hawaii
PACIFIC OCEAN

6. a. On the map above, place an X where you live.

   b. How many populations of gray whales remain?

   c. Where are they located?

STORM TRACKING AND
SURVIVAL IN COLD WATER

TEACHER BACKGROUND - October 1 and Storm Warning

"October 1" begins our exploration of one of the most incredible migrations known to man. Following a migratory path of 5,000 to 7,000 miles, the California gray whales swim from their summer feeding grounds in the far north of the Bering Arctic to their mating and calving grounds in the shallow, tidal lagoons of western Baja California and the northwestern shores of mainland Mexico. This migration will provide the backdrop for the readings and activities which follow.

"October 1" follows the gray whales to the Bering Straits. The weather conditions our whale encounters provide a springboard for the activity "Storm Warning". "Storm Warning" is a four part activity. Part A begins with a discussion of longitude and latitude and then provides a storm tracking chart on which your students will plot the course of a storm in the North Pacific Ocean. Part B adds a fishing boat to the storm tracking chart and concludes with a recommendation from your students to the skipper of the fishing boat. Part C presents a factual history of near disaster at sea. Part D picks up the dangers faced by the crew of the vessel sunk in Part C and offers a discussion of hypothermia. The material on hypothermia is especially valuable to your students if you are planning field trips in connection with your course. Even if your plans do not call for field tripping, your students' plans most certainly will. The information, which comes from several sources including Girl Scouts Camping Standards #77, is valuable for anyone working or playing in the out-of-doors.

Duplicate the activity pages. One set is recommended per student. This activity is best performed by individuals or pairs. Although Parts C and D lend themselves best to homework assignments, it is possible for your students to complete all four parts as either in-class assignments or as homework assignments. The method you select will depend upon the needs and expertise of your particular class. World maps, an atlas and a globe provide useful teaching aids for Parts A and B. The concepts of longitude and latitude are most easily seen on a globe. You will likely need to provide a refresher in plotting techniques and the use of degrees in numbering longitude and latitude. Upon completion, plan to provide time for a discussion of the concepts presented. During your discussion provide the correct answers to the questions found in the student text pages.

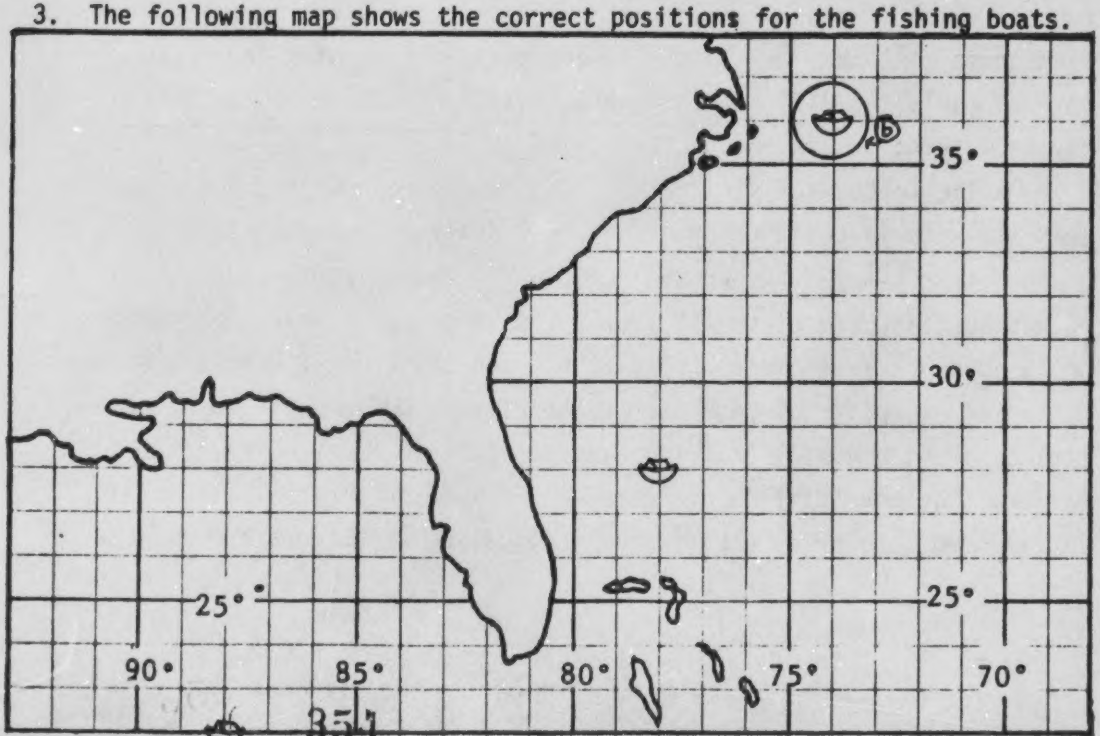
KEY

October 1

1. The major difference between the two tails lies in the fact that the whale's tail is "horizontal" while the fish's tail is "vertical". Your students may miss this most obvious difference and note that fish tails have rays while whale tails do not. Other possibilities such as presence vs. absence of scales, etc. exist. In your discussions, however, emphasize the difference in orientation of the tails.
2. Three functions of whale blubber include:
   a. insulation from cold water
   b. flotation
   c. food storage
3. Our whale probably uses her blubber to provide energy for her swim south through the Bering Straits.

Storm Warning - Part A

1. Latitude lines tell us the distance (in degrees) north or south of the equator.
2. Longitude lines tell us east-west distance.
3. The following map shows the correct positions for the fishing boats.



Part A - Procedure

2, 3, 4. A correctly completed storm tracking chart follows this section.

5. a. The storm will pass through the strait on October 31.

   b. The storm will have a greater effect on the whales because they must come to the surface to breathe.

Storm Warning - Part B

1. a, b. A correctly completed storm tracking chart follows this section.

2. a. At 12 miles per hour it will take the *Lady Mary* about 3 days to reach the Bering Straits.

$$\frac{864 \text{ miles}}{(\text{ie. } 12 \text{ miles/hr.} \times 24 \text{ hrs./day}} = 3 \text{ days}$$

   b. The storm tracked in Part A will reach the Bering Straits on October 31. (This question was already answered in 5.a above but is repeated here to set the stage for the next question.)

   c. Hopefully, your students will advise the skipper of the *Lady Mary* to alter their course and return to a weather-safe port.

Storm Warning - Part C

1. This question provides those "weather observers" who advised the *Lady Mary* to sail on a chance to change their advice. This story was included to show the very real power of the sea and the danger that can lie therein.

2. A number of actions might have helped. A temporary patch over the hole on the inside might have slowed the inflow sufficiently to let the bilge pump empty the boat. A temporary patch made of plastic sheeting could have been put over the outside. Knowing the proper radio techniques (call MAYDAY, MAYDAY. Give the name and position and nature of difficulty. Then get off the air.) might have helped. Pre-trip maintenance and checks would have prevented most of the problems. Your students will have many other ideas. The following "points to ponder" come from the Oregon State University publication "*Starfisher's* Last Voyage", by Edward J. Condon, from which the material in the student text is excerpted.

Points to Ponder

1. What went wrong on Starfisher? The seam probably opened because the Barlows had not had her recalked in quite a long time. Wood boats need continual tender loving care. Without it their enemies --"dry rot" (really fungi), marine borers, normal wear and tear-- inevitably will put them in danger of sinking.

2. Could the Barlows have stopped or slowed the flooding? They should have stuffed the open seam from the *inside*, with rags, paper, anything that could plug the hole; then they should have nailed a temporary patch in place until they could make port. They could have slowed the leak considerably just by lashing a canvas, heavy plastic sheet, tarp, or even bed sheet to the *outside* of the hull, over the open seam.

3. What went wrong with the bilge pump? Why? Bilge suction is normally located at the low point of the bilge. Unless you take the pains to clean the bilge, you can count on clogging the bilge pump. In most hulls, the suction is located where it is difficult to clear when it *does* become fouled. The best precaution is to keep bilges clean.

4. What lessons can be learned from the missing standby pump? The obvious lesson is not to go to sea until quick checks ensure that *all* life-sustaining equipment is indeed *on board* and *in working order*.

5. What went wrong with the lifeboat? Two strong probabilities are: (a) in their excitement, the Barlows forgot the drain plug in the bottom of the lifeboat (This plug is normally kept out when a boat is out of water for long periods); or (b) if the lifeboat had sat on deck for a long time, the sun had dried (shrunk) the calking.

6. What happened to Starfisher's radio? Perhaps nothing. Most likely, this was another example of poor maintenance: the brothers had probably not maintained the radio properly over the years. Marine radios are extremely reliable but do need periodic service checks by qualified electronics technicians. Then, what channel did Tim use

for his distress message? Was it one of the *International Distress Frequencies*, which are monitored constantly by all U.S. Coast Guard stations (and by most ships and many boats at sea)?

7. Did Tim use the radio distress code word (the word that alerts all listeners for the message to follow)? It's MAYDAY, MAYDAY. Next proper procedure calls for giving the name of your vessel, your approximate position, and the nature of your difficulty. Don't jam the radio by transmitting continuously. Repeat your message twice every 10 minutes or so, and get off the air so someone can acknowledge your call.

8. What are the visual and audio signals for a boat in distress in daylight hours? At night? *Visual signals:* In daylight, flying the flag upside down is a generally recognized distress signal. At night, use a light to flash the Morse code letters SOS (short-short-short...long-long-long...short-short-short), repeated over and over again. Point the light directly at the other ship, boat, or airplane--or at houses on the beach. A *red* flare is a distress signal. *Audio signals:* Ringing your boat bell and blowing its horn are distress signals if someone is close enough to hear them.

9. Why didn't the large ships stop and assist? Ships see thousands of boats on any given voyage. Unfortunately for the Barlows, many boats at sea flash lights at ships at night, just to ensure that the ships see them--and won't run them down. In this case, the two freighters would have stopped if they had received an SOS by light, had seen a red flare, or had heard the whistle and bell--or (better yet) had both seen light and flares and heard whistle and bell.

10. Where were the lifejackets? Like other seldom-used equipment on Starfisher, the lifejackets were probably stowed in some forgotten nook, and had not been inspected in years.

Storm Warning - Part D

1. a. With flotation devices, the Barlows could survive for about 3 hours.
   b. With life-jackets, the Barlows could survive for about 2 hours in 5°C water. Flotation devices greatly increase the survival time by reducing energy losses (less energy is required to stay afloat).
2. Hypothermia is the condition of lowered, deep-body temperature.
3. Answers will vary depending on your students' knowledge of hypothermia. Most of your students will suggest ways to help which involve warming. This question is included to get your students thinking in terms of dealing with emergency situations. Specific preventative and treatment measures are found in the section of the student text following question 3.
4. "When your feet are cold, put on a hat." This advice seems strange until it is coupled with the fact that up to 50% of body heat loss occurs from the head.
5. Several layers of clothing provide better insulation than one heavy garment.

6, 7. These are activities your students should do before you "field trip."

8. Constant swimming, splashing, and shouting decrease survival chances because they increase the rate at which you lose body heat. The faster the heat loss, the shorter the time you can survive in cold water.
9. Additional pre-trip activities.
10. The administration of alcohol to hypothermia victims causes surface blood vessels to dilate, increasing the amount of heat lost and compounding the victim's problems.
11. Additional pre-trip activities.
12. H.E.L.P. is a Heat Escape Lessening Position resembling the fetal position. H.E.L.P. can significantly increase survival time in cold water.
13. Additional pre-trip activities.

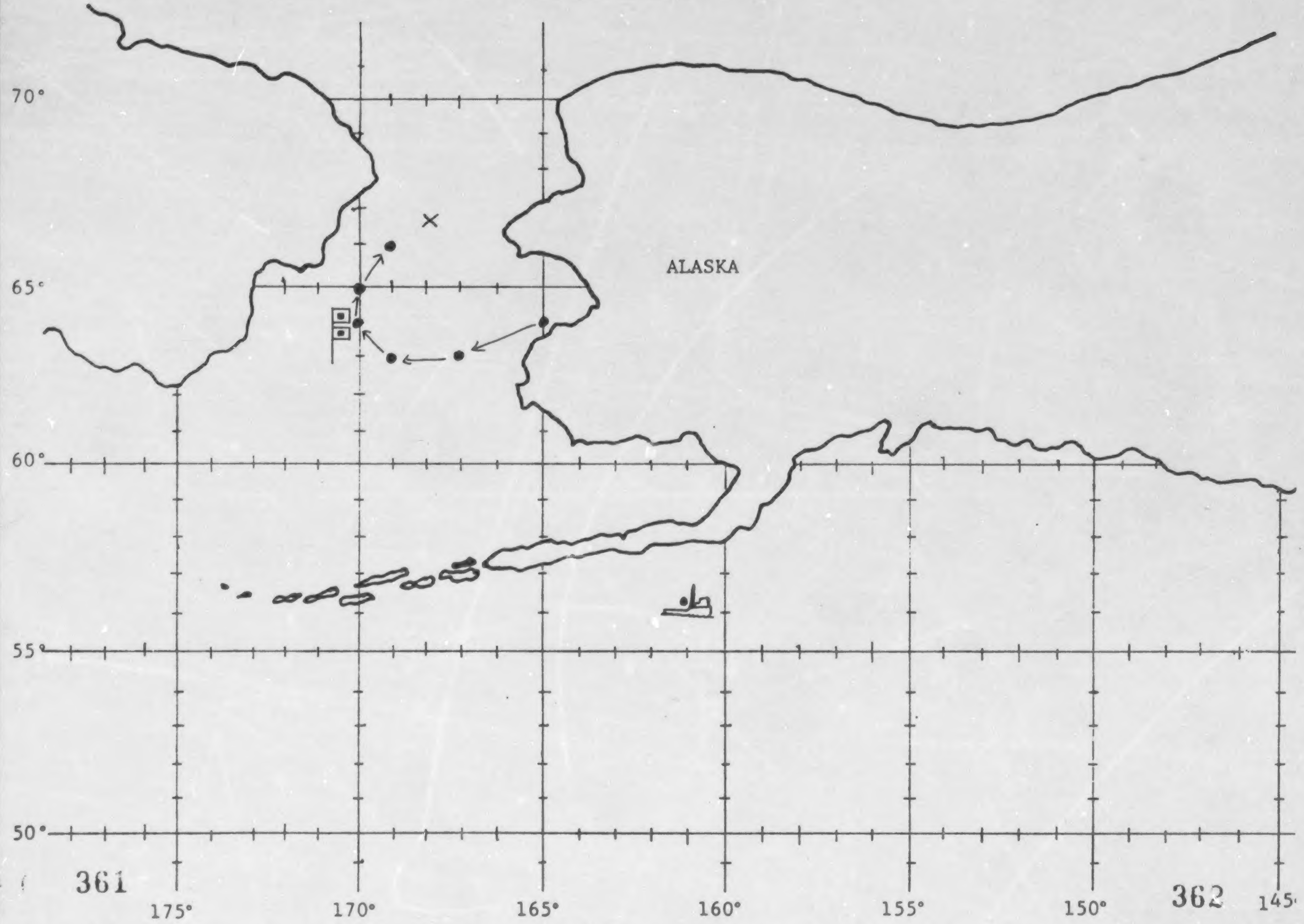
14. a. Shivering, cold hands and cold feet may be treated by helping the victim put on dry clothes. Providing warm, dry shelter is also effective treatment.
    b. The time to treat these symptoms is as soon as they appear. Delay increases the danger of hypothermia.
15. Finding or rigging shelter and rewarming is the treatment recommended for people in the stumbling and numbness stage of hypothermia.
16. Loss of memory and slow, slurred speech in hypothermia victims occur because the brain's thought control centers are starved for warm, oxygen-rich blood and, as a result, start to shut down.
17. At this advanced stage of hypothermia, cold shock to vital organs, abnormally low blood pressure, and chemical imbalances may be fatal, even hours after warming treatment has apparently "cured" the victim. After warming MEDICAL ASSISTANCE IS CRITICAL.
18. The first three groups of symptoms of hypothermia are:
    a. shivering, cold hands and cold feet.
    b. clumsiness, loss of dexterity.
    c. loss of reason and recall.
19. Keeping the victim's head low and feet up gets warm blood to the head first.
20. Of the four techniques mentioned, hot towels, warm air, and buddy-warming may be used on unconscious victims.
21. The obvious message in this question is that planning ahead and recognizing potential danger situations reduces the risk of hypothermia.

KEY WORDS

blooms
blubber
bouyancy
collapse
core
counteract
cyclone
degrees
dexterity
equator

fiber
flotation device
flukes
flurries
gale
groin
hemorrhage
hypothermia
hurricane
immersed
insulate
latitude
leisurely
longitude
mariners
maximize
minke whale
mobile
numbness
plankton
pole
position
prevention
respirators
rigidity
scale
slurred
small craft advisory
storm tracking chart
straits
survival
symptoms
syndrome
trunk
venture
victim
weather

STORM TRACKING CHART


70°
65°
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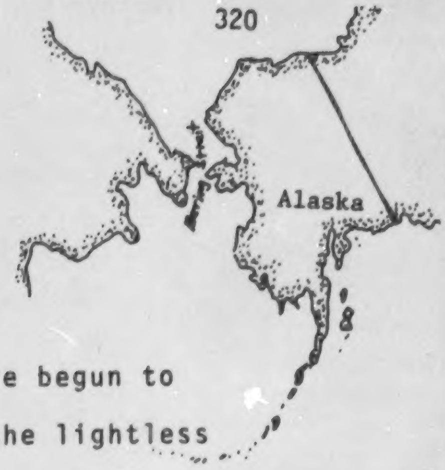
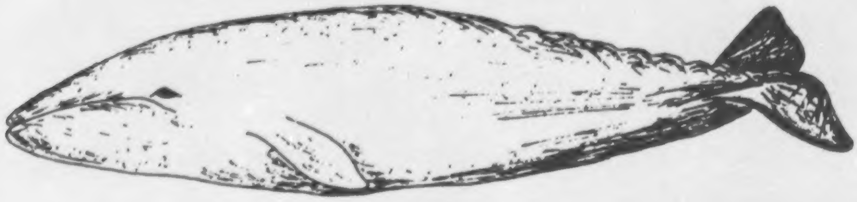
50°
ALASKA
175°
170°
165°
160°
155°
150°
145°



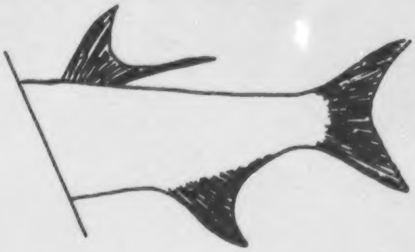
OCTOBER 1

The long days of the arctic summer have begun to shorten. Life in the arctic prepares for the lightless days to come. A chilling north breeze blows across the pack ice. Like so many nights for the past three months, our whale has spent the entire night feeding. But this morning there is something different in the air. In response to this change, she begins to swim to the southeast. She has begun her long swim.



During the next few days she stays close to shore. Her swimming is leisurely (relaxed) but her motion is always southward. As the days pass, her swimming becomes more purposeful. Each stroke of her huge tail flukes move her south.

1. Compare a whale fluke with the picture of a fish tail that follows. What is one major difference between the two tails?



The cold water rushes along the whale's skin as she swims. Three months of constant eating have given our whale a thick layer of blubber. This blubber helps insulate her from the cold water. Blubber is lighter than water. As such, her blubber also helps counteract the heaviness of her body. Blubber helps her float. Her blubber serves one more important role. The blubber is used as food storage.

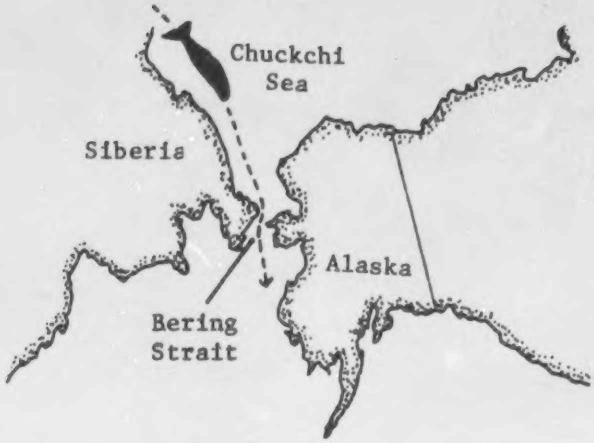
2. What are three functions of whale blubber?

a.

b.

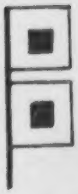
c.

Along Siberia's shallow coasts, she swims eastward through the Chuckchi Sea. Her progress slows occasionally as she feeds on scattered, dense, plankton blooms.



The sun is low on the horizon. Only a few weeks remain if she is to get through the Bering Strait before the bitter storms. Each day brings more flurries of snow. The noon sun is cold and lifeless. Soon these waters will be covered with a thick layer of ice. Our whale is now swimming with other gray whales and minke whales. All are racing the ice to the narrow straits. The land turns to the south. The whales also turn south and pass through the strait into the Bering Sea.

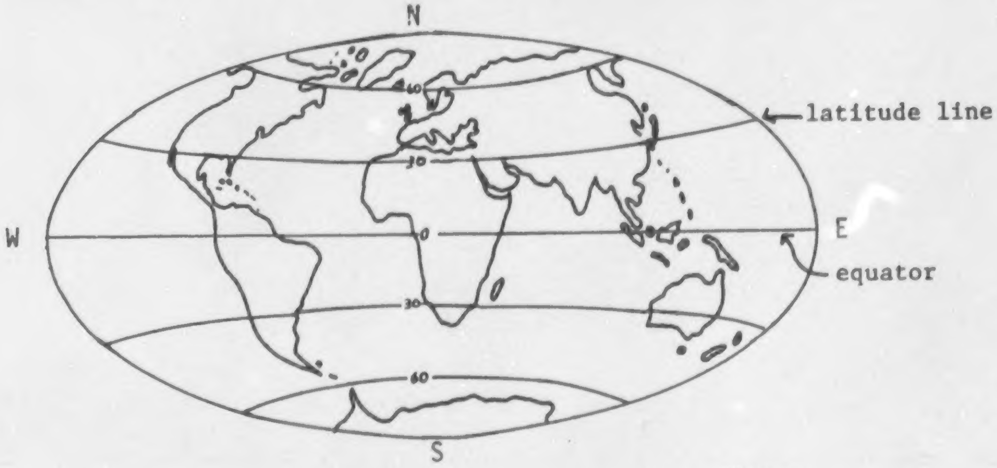
3. During her swim through the Bering Straits our whale does not eat. What does she probably use as an energy source to keep her swimming?



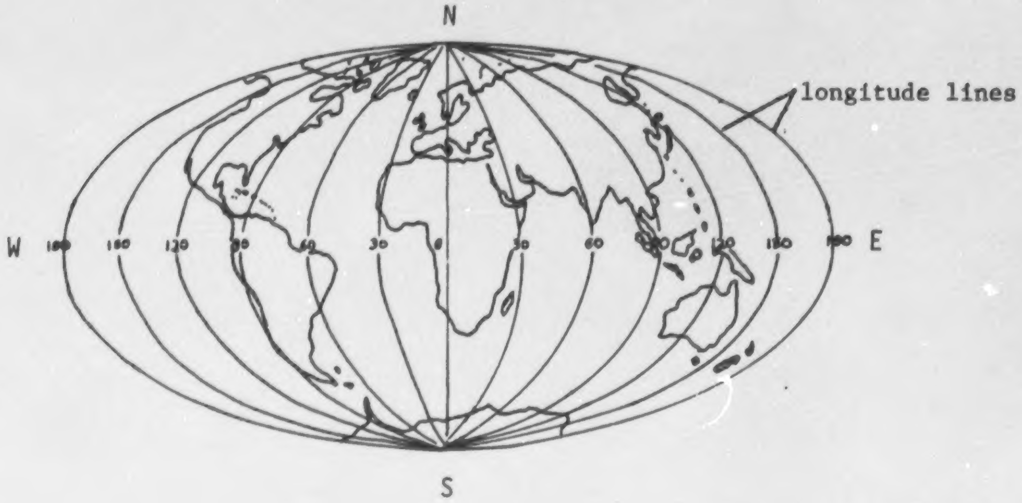
STORM WARNING

Whales are not the only animals that race the ice to the Bering Strait. The crew of the ice-breaker Polar Star also turns south. As a mobile weather station, the The Polar Star provides information to other ships in the area.

The Coast Guardsmen on board the Polar Star broadcast the position of storms. A message from the Polar Star saying "There is a storm centered 100 miles from here" would be of limited use. Where is "here"? To help mariners locate their position, imaginary lines are drawn over the surface of the earth. These imaginary lines are called latitude and longitude. First a line called the equator is drawn halfway between the north and south poles. Evenly spaced lines are drawn from the equator to the north pole and from the equator to the south pole. These evenly spaced latitude lines tell us the distance north or south of the equator.



Longitude lines are drawn from the north pole to the south pole. Notice on the picture below that longitude lines get closer together as you leave the equator. Longitude lines tell us east - west distance.


N
longitude lines
W
180
150
120
90
60
30
0
30
60
90
120
150
180
E
S

1. What information do we get from latitude lines?

2. What information do we get from longitude lines?

Latitude and longitude are given in terms of degrees. The zero latitude line is the equator We can give a part of a location as "ten degrees north latitude". This tells us the location is north of the equator and how far. The zero longitude line runs through Greenwich, England. A combination of a latitude and longitude reading will pinpoint any place on earth. For example, there is only one place that would have a reading twenty-two degrees north latitude, eighty-eight degrees west longitude (22°N 88°W).

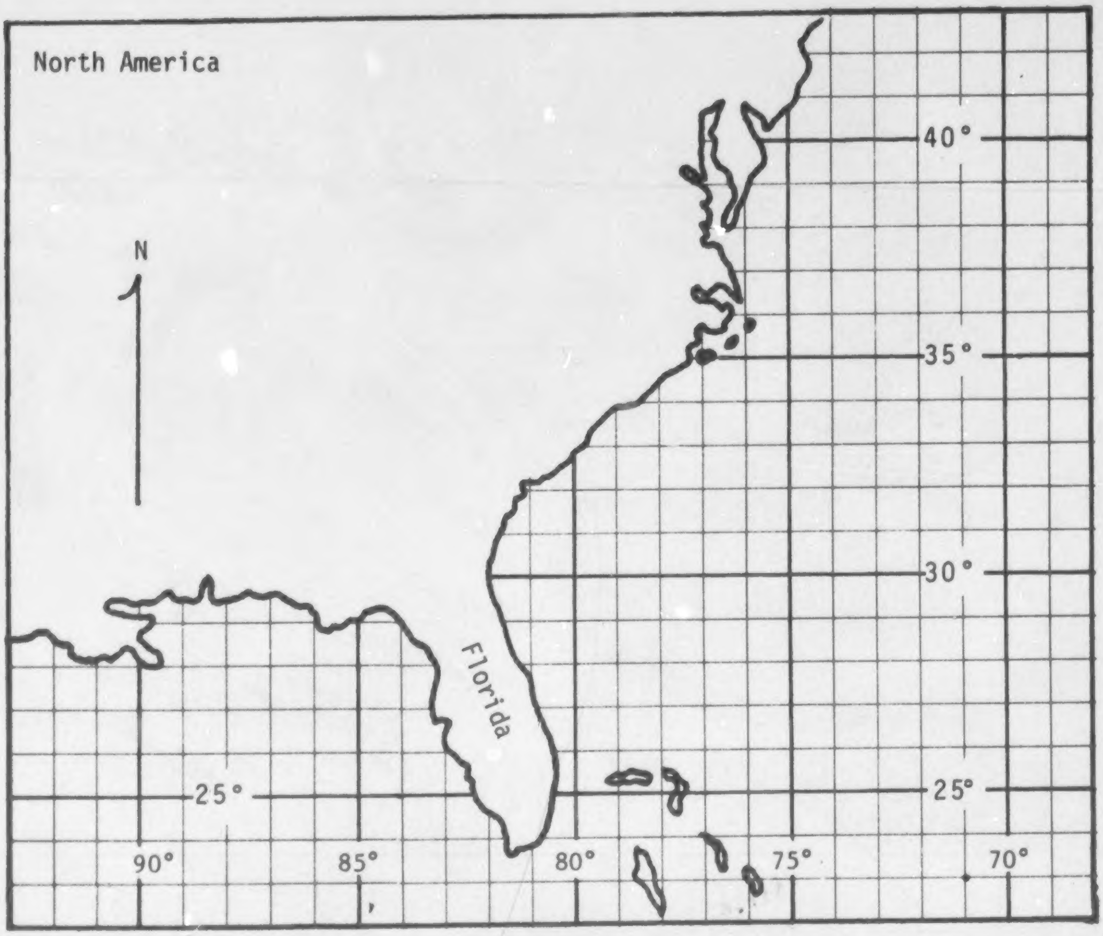
3. The map below shows a portion of the Florida coastline. Three shrimp boats are fishing at the following points.

   22°N 88°W   28°N 78°W   36°N 74°W

   a. Draw each of the three shrimp boats in their proper location.

   b. Circle the boat that is furthest north.

   c. Make an X below the boat that is furthest west.



Just as you pin-pointed the location of the shrimp boats, weather watchers can pin-point the location of storms. In the following activity you will have a chance to see how weather information is transferred. You will also have a chance to see the importance of weather to mariners.

Materials:

storm tracking chart
pencil

Procedure:

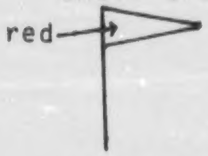
1. Obtain a storm tracking chart which shows the shoreline of the North Pacific Ocean.
2. The Polar Star is watching a storm moving into the Bering Straits. They have broadcast the following positions for the center of the storm:

October 29 -	midnight	64°N	165°W
	noon	63°N	167°W
October 30 -	midnight	63°N	169°W
	noon	64°N	170°W
October 31 -	midnight	65°N	170°W
	noon	66°N	169°W

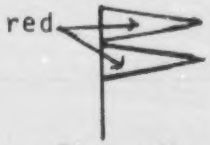
Plot these positions on your storm tracking chart. Plotting is easy. First, find the location of the storm at each time. Then make a dot on the map at that location.

3. Connect the dots from midnight October 29 through noon October 31 to see the path of the storm.
4. The speed at which a storm moves tells something about its winds. Windspeed, however, is usually greater than the speed at which the storm moves. The weather service displays storm warning flags to alert mariners. The following warning flags alert mariners to wind conditions.

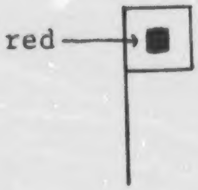
Small Craft Advisory: One red pennant flying indicates winds from 21 to 34 knots. (24 mph to 39 mph)



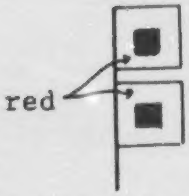
Gale Warning: Two red pennants indicate winds from 35 to 47 knots (40 mph to 54 mph)



Storm Warning: One red flag with a black center indicates winds 48 knots and above. If the winds are associated with a typhoon or hurricane, the storm warning flag indicates winds from 48 to 63 knots (55 mph to 72 mph)



Hurricane Warning: Two red flags with black centers are used only in connection with typhoons and hurricanes to indicate winds 64 knots and above. (above 72 mph)



4. On October 30 the Polar Star detects 65 knot winds at noon bearing. On your storm tracking chart, draw in the warning flag the weather service would use to alert mariners.

5. Whales are moving through the Bering Straits as the storm approaches.

   a. On approximately what day will the storm pass through the strait? ______________________________

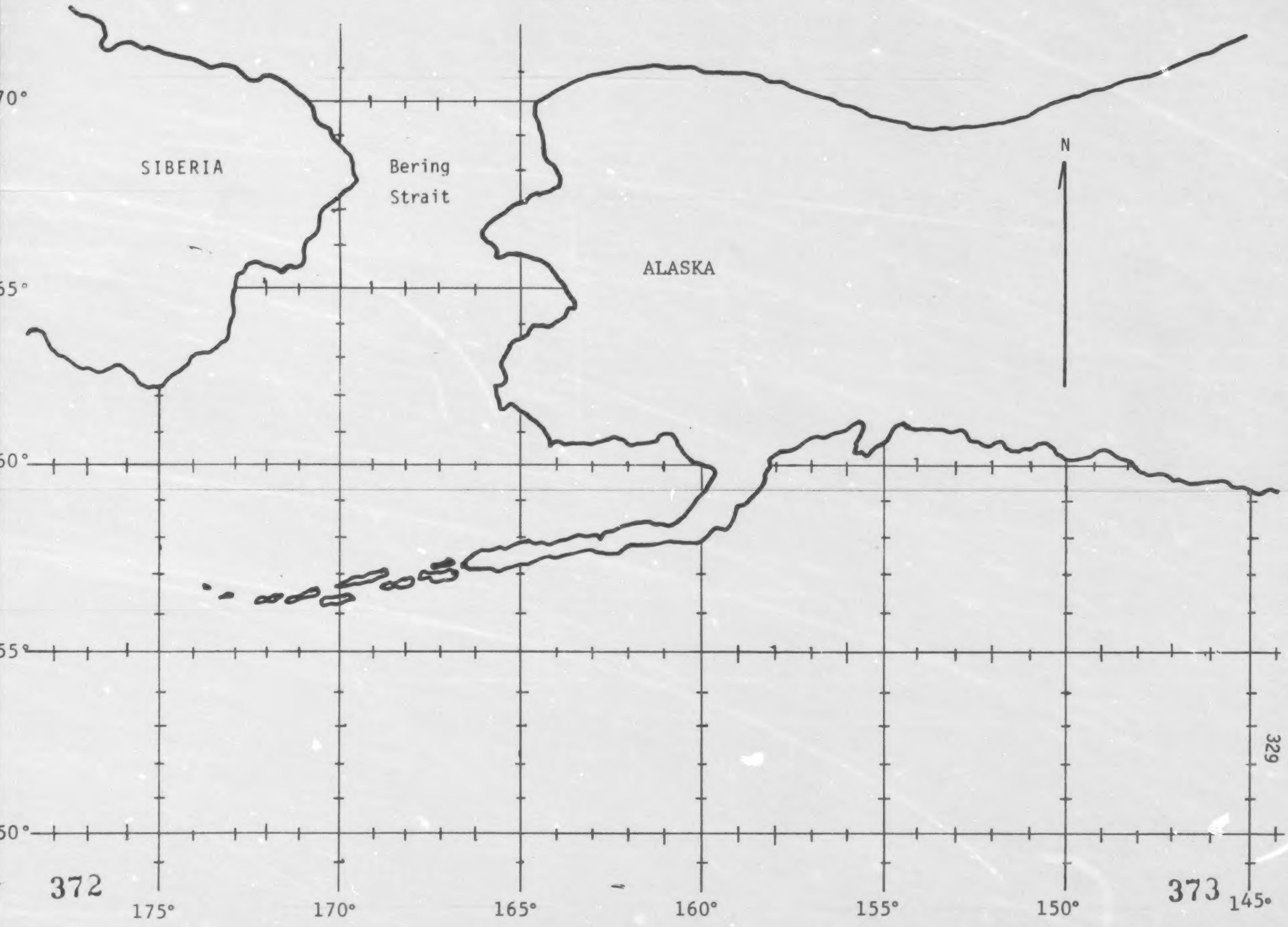
   b. Will the storm have a greater effect on the whales or on the fish in the straits? Why? __________

   ____

   ____

   ____

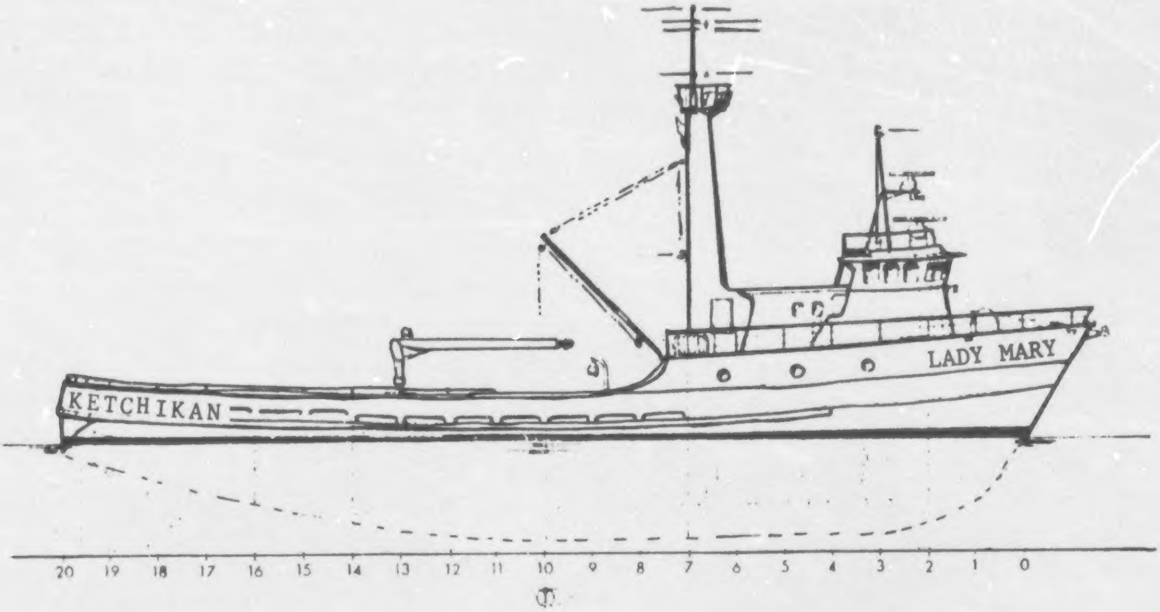
STORM TRACKING CHART


SIBERIA
Bering
Strait
ALASKA
N
70°
65°
60°
55°
50°
175°
170°
165°
160°
155°
150°
145°

Part B

"Polar Star", this is Whiskey X-ray Tango two two five, the Lady Mary, requesting a weather check."

1. WXT 225, Lady Mary, is a 130 foot crab boat out of Ketchikan, Alaska bound for the Bering Strait. Its position at noon on October 29 is 56°N 161°W.



   a. Mark the position of the Lady Mary on the storm tracking chart you used in Part A.

   b. Put a small X on the center of the Bering Strait.

2. The Lady Mary cruises at 12 miles per hour. Her position puts her about 864 miles southeast of the Bering Strait.

   a. At her cruising speed, how long will it take her to reach the straits? (Hint: distance = rate X time)

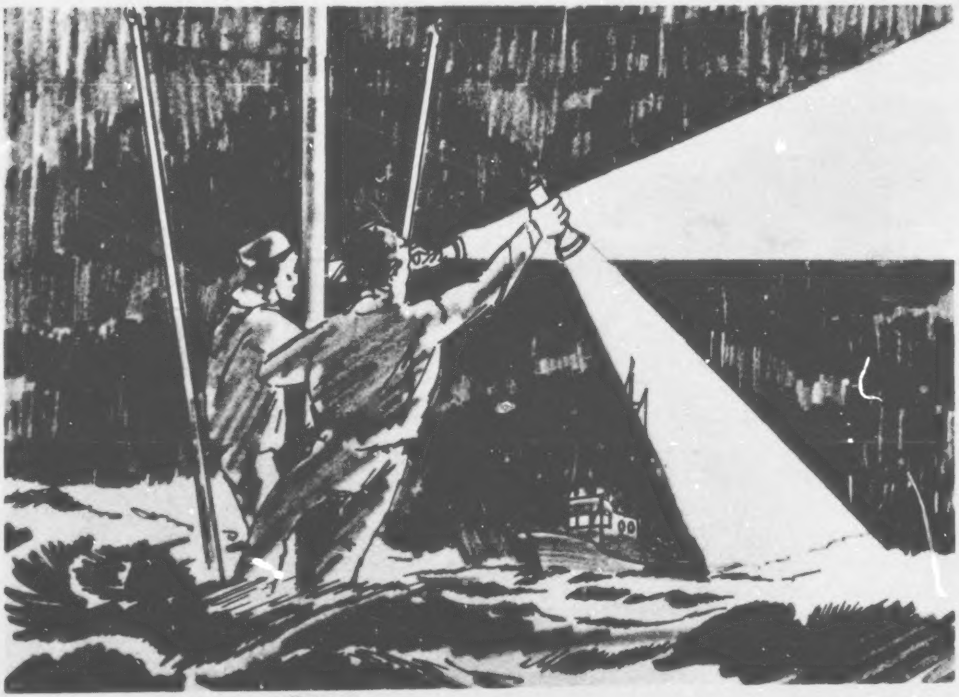
b. When will the storm tracked in Part A reach the Bering Straits?

c. As weather observer on the Polar Star what advice would you offer the skipper of the Lady Mary?

Part C

The crew of the Lady Mary run a "tight ship." Not all fishermen do the same. The story below is based on fact.

Starfisher's Last Voyage



This story is based on fact, even though the names are fictional, and incidents have been added in reconstructing the original news story. The list of what went wrong on Starfisher *may seem exaggerated ("Could all* that *happen?"), but sinkings more often than not are the result of a train of misfortunes or errors. Usually, only a few errors are enough to sink a boat—and when a defective lifeboat is added to the chain, no one returns to tell the story. So follow the trials of the Barlow brothers; maybe we can all learn from them . . . and save some lives in the future.*

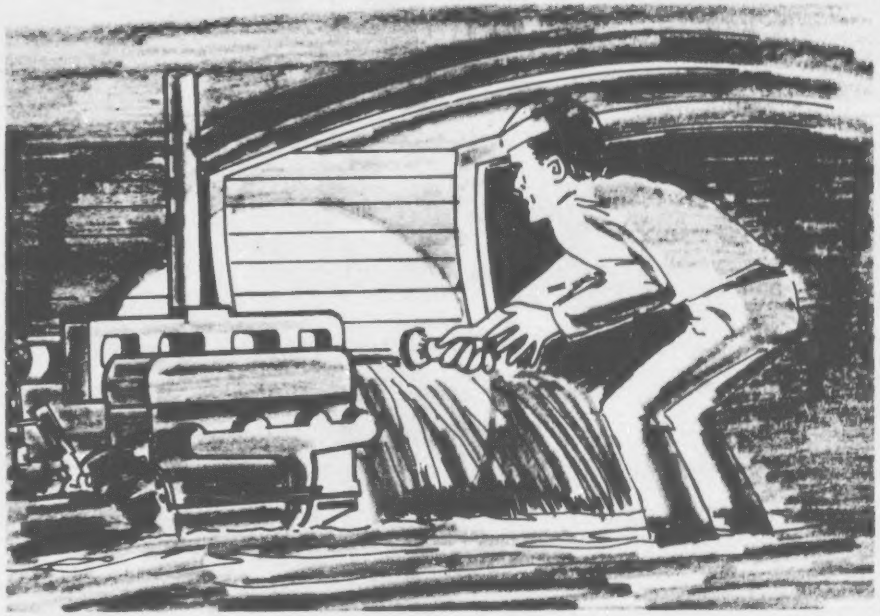
Arlo and Tim Barlow, brothers who had made many fishing trips together, got their 12-meter combination boat, *Starfisher*, underway one night last March for a one-week trip to the local fishing grounds.

As they cleared the inner harbor, they felt *Starfisher* start to work in the large swells coming into the outer harbor. After clearing the sea buoy, they set course for the fishing grounds, ignoring the heavy swell, and both brothers settled down to their at-sea routine.

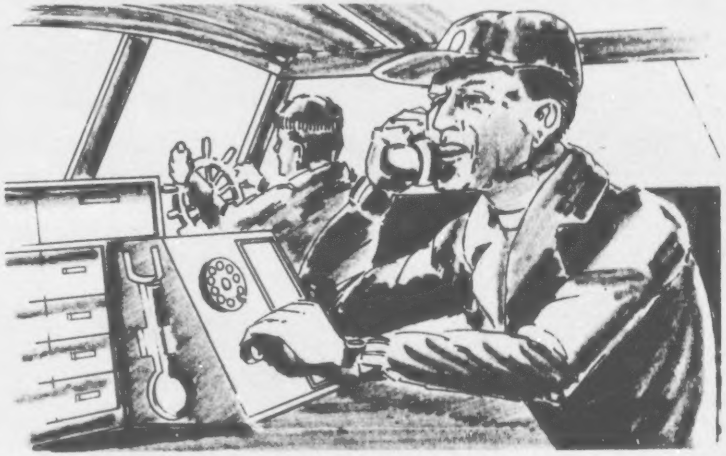
Before they were two miles beyond the sea buoy, *Starfisher's* motion became labored—she hesitated before righting herself after each swell passed beneath. As *Starfisher* hung up on one particularly large swell, almost refusing to right herself, Arlo decided he had better see if everything was in order.

Shining a light into the engine compartment, he saw that the boat was taking water. Her motion in the swells had apparently opened a seam in the engine compartment, and the bilge pump was not staying ahead of the rising water.

Arlo told Tim to send the distress signal on the radio while he tried to put the other bilge pump on the line . . . . Within 20 minutes, both the engine compartment and the adjacent fish hold had flooded (*Starfisher* had a common bilge for both spaces).



The bilge pump was not staying ahead of the rising water.



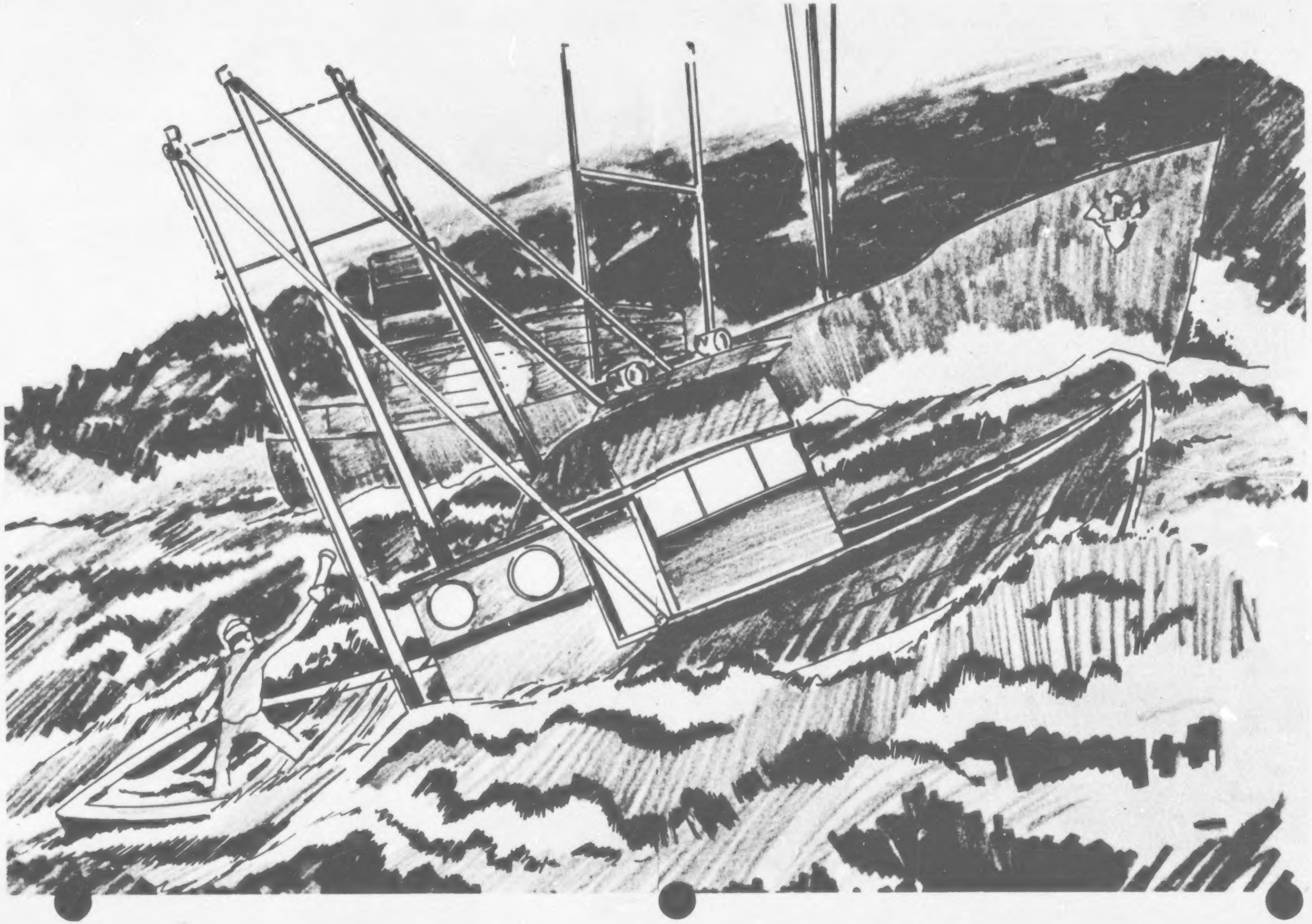
Tim had no luck raising anyone on the radio.

Tim had no luck raising anyone on the radio. Then, much to his relief, he saw the lights of not one but two ships bearing down on *Starfisher*. He thanked heaven that his problem was solved.

Just to be sure that the ships saw him, Tim flashed a spotlight at first the bridge of one and then the other . . . . Moments faded into minutes. Neither ship slowed or gave any indication it had seen *Starfisher*. Both passed and eventually disappeared without even acknowledging *Starfisher's* presence.

Meanwhile, Arlo found that the bilge pump driven by the engine had clogged with debris from the bilge and was no longer working. He could not find the standby pump, though

Neither ship slowed or gave any indication it had seen Starfisher.



he was sure he had told Tim to pick it up at the repair shop the day before. He realized then it must not be aboard.

Arlo clambered topside, to find *Starfisher* so low in the water that seas were washing over the deck. A quick—and unprintable—exchange between the brothers made it clear the situation was hopeless; it seemed their best bet now was to abandon *Starfisher*.

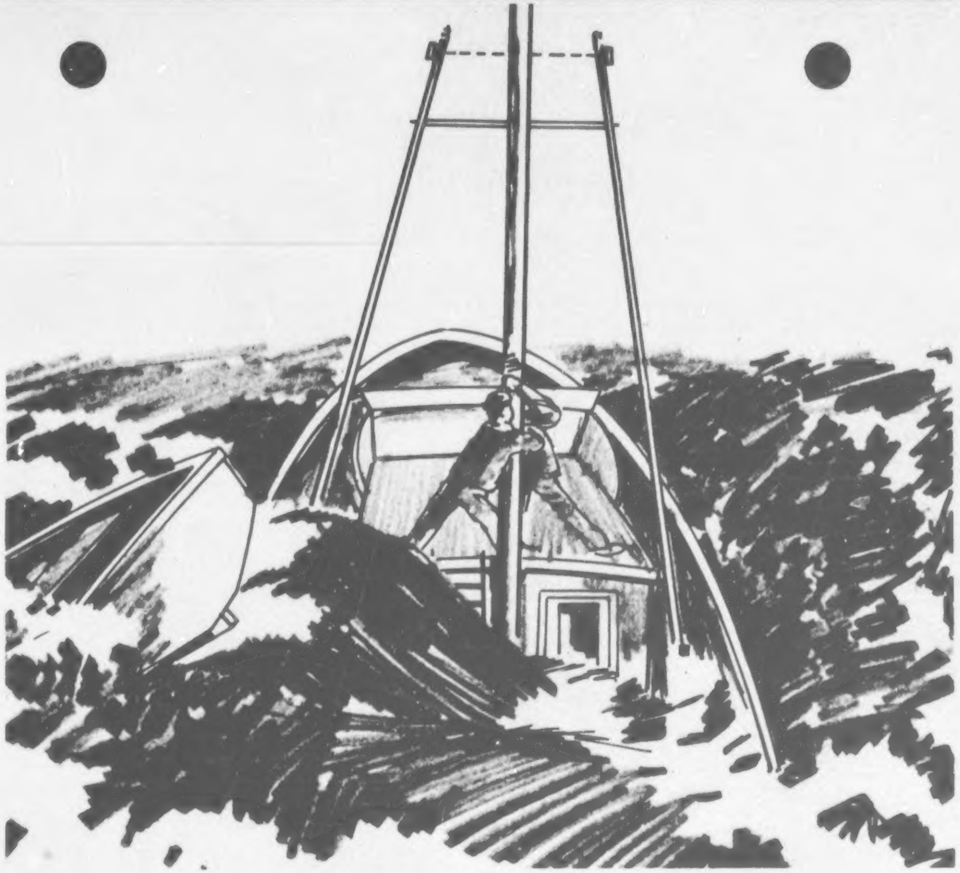
With that, they unlashed the lifeboat, tenderly lowering it alongside, and wasted no time climbing in. As they cast off, they realized with a shock the lifeboat was *also* taking water—worse yet, it began to sink faster than *Starfisher*. They made a jump for *Starfisher;* within moments the lifeboat capsized and sank.

At this stage, the brothers decided to put on their lifejackets and stick with *Starfisher* as long as she remained afloat. A frantic search through the now-flooded cabin revealed no lifejackets, so without them both men climbed the mast as *Starfisher* continued to settle. Clinging to the mast, Arlo and Tim were reduced to signaling with their flashlights to try to attract attention.

They chanced to live and tell about their misadventure because a fellow fisherman became curious about those peculiar lights. Captain Jack von Kelly later said it was the weirdly flashing lights that prompted him to take a look before he returned to port. His curiosity almost certainly saved the Barlow brothers.

The moral? Not maintaining the equipment on a boat is like playing Russian roulette . . . eventually the odds will catch up.

The sea may forgive a careless error or two, but those who compound one error into a series of mistakes ***and return to tell about it*** are few and fortunate.



Arlo and Tim climbed the mast as* Starfisher *continued to settle.

1. Would you like to change the advice you gave to the skipper of the Lady Mary in part B, 2.c.? If so, what is your new advice?

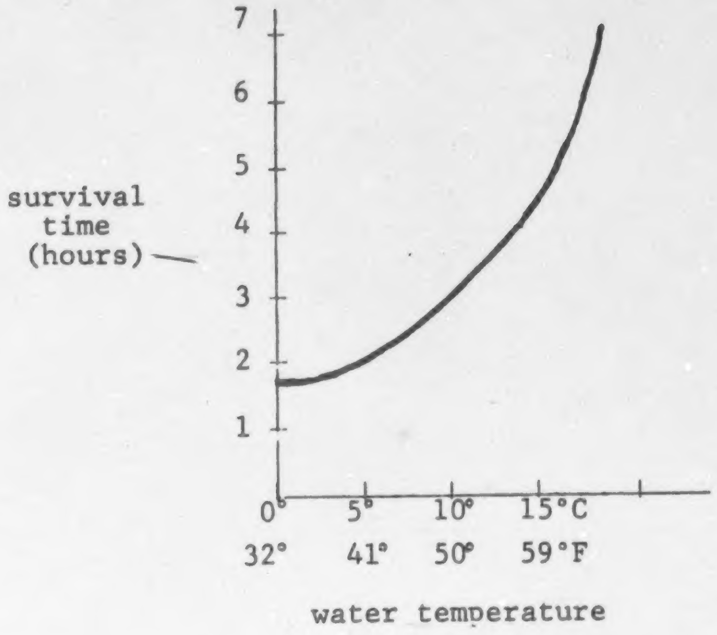
2. What is one action that the Barlow brothers might have taken to increase their survival chances?

Part D

What would have happened to the Barlows if Captain Jack von Kelly took longer to reach the Starfisher? How long could Arlo and Tim have survived in the cold water? What could they (or you) have done to survive?

The temperature of the water is a major factor in determining how long the Barlows could have survived. In 10°C (50°F) water the brothers predicted survival time without lifejackets would be one and a half to two hours. In 5°C (40°F) water survival time is reduced to about 30 minutes.

1. Flotation devices (life jackets) increase the predicted survival time. The graph below shows survival time for "average" men and women wearing a life-jacket.



a. With life-jackets, how long could the Barlows survive in 10°C?

(Hint: This is easy. Draw a line straight up from the 10°C water temperature to the curve. From the point where the line meets the curve, draw a straight line over to the survival time-line. Read the number from the scale on the survival time-line)

b. With life-jackets, how long could they survive in 5°C?

How does cold water kill? The answer is hypothermia. What does that mean? Hypothermia means low (hypo) temperature (thermia). We use it here to mean lowered, deep-body temperature. Hypothermia occurs when the body loses heat faster than it can produce heat. In cold water, the skin becomes cooled very rapidly. It takes 10-15 minutes before the temperature of the heart and brain begin to cool. Unconsciousness can occur when the deep-body temperature falls to about 90°F (32°C). If the temperature continues to fall, heart failure usually causes death when the body "core" cools to about 80°F (30°C) or below.

2. What is hypothermia?

3. What might be something you could do to help a person with hypothermia?

The Barlows were in danger because they were immersed in water. Hypothermia can also strike unsuspecting people on the beach or in the mountains. Here are some things to do to avoid hypothermia.

BE PREPARED !

AN ALERT MIND IS THE BEST SURVIVAL TOOL!

Plan ahead for emergencies:
- File trip or float plan
- Plan checkpoints and signals
- Monitor the weather
- Enforce the buddy system
- Select a sensible leader
- Keep a positive outlook!

A PREPARED BODY IS THE BEST SURVIVAL KIT!

Be in good condition and carry gear to:
- Stay dry (rain gear, spare large plastic bag)
- Stay warm (spare wool layers, a hat)
- Fuel up (energy foods, hot drinks)
- Produce heat (dry tinder, waterproof matches)
- Stay afloat (life-jacket)
- Signal distress (whistle, light, flares)

+STAY WARM!

PROTECT CRITICAL HEAT-LOSS AREAS:

- "When your feet are cold, put on a hat." From 25% to 50% of total body heat loss radiates from the head.
- Assume HELP position to protect sides of chest and groin, other major areas where blood vessels are close to the surface.
- If in water without flotation, don't drownproof (relaxed, face down floating)- with the head under water the combined effect of major head heat-loss and faster water conductivity cuts survival time drastically (75%!). Slowly treading water is twice as effective as drownproofing.

MAXIMIZE INSULATION:

- Wear layers of wool clothing rather than one heavy garment. Layers insulate as body heat warms the trapped air. Top layer should be windproof and waterproof. Apply this to feet too...leather or rubber shoes are warmer than canvas.
- On water, wear PFD (Personal Flotation Device = life-jacket) on top of other layers. Insulating properties of a float coat quadruple survival time. Fitted foam vest triples time, with kapok vest, then bib-type PFD's least warm.
- Keep collar, hood, and cuffs snug to prevent moving air or water from exchanging cold for warmed layers.
- Insulate against cold surfaces. Avoid sitting, kneeling, or lying down without padding (grass, leaves, newspapers.)
- Wear gloves when handling cold objects.
- Keep metal tools, knives, axes, sheathed away from the body.

5. Why is it better to wear several layers of clothing rather than one heavy garment?

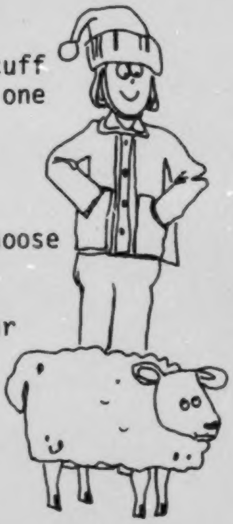
6. BEFORE VENTURING OUT IN THE COLD, DO THESE EXPERIMENTS.

Compare cotton and wool when wet. Dip a cotton sweatshirt cuff and a wool sweater cuff into about an inch of water. Watch one "wick".

a. Which would stay drier and warmer?

Put on one wet wool sock and one wet cotton sock (you may choose to use a glove, or sleeve).

b. Which feels warmer? In a "wind"? (Have someone fan your sock with a piece of cardboard).



GARBAGE BAG

+STAY DRY!

- Cover up before getting wet or change to dry clothes and keep them dry! Wet clothes lose up to 90% of their insulating value.
- Wear wool. It is still 40-60% effective even when wet.
- Avoid cotton. It "wicks," spreading moisture from fiber-to-fiber making a larger area to cool by evaporation.
- Avoid plastic alone. It has poor insulating qualities and body moisture builds up inside unless well ventilated.
- Avoid wearing a poncho in wet or windy weather. It "leaks" - moisture drips in and heat flows out. Keep one handy to rig a shelter or windbreak.
- Keep up "loft" of down. If down gets wet or matted, insulating air spaces between feathers are lost.

7. BEFORE VENTURING OUT IN THE WET, TRY THIS:

Test foul-weather gear when under a shower or sprayed by a hose. Exercise and perspire in foul-weather gear.

a. Does it leak?

b. Does it "breathe"?

+SLOW DOWN !

- "Quit while you're ahead!" means to quit while your head can still think safely. Cool blood slows, delivers less oxygen; the brain suffers. Use energy only to make things snug and sheltered before reserves and reason are lost.
- Reduce perspiration by reducing activity. Perspiration means the body is dumping heat and moisture. Energy can go into producing heat rather than motion if the body is at rest.
- Make short rest stops. Five to seven minutes is long enough for muscles to relieve the "tired feeling."
- Rig a distress signal to show without constantly expending more energy. Wave, splash, shout, or whistle only when rescuers are likely to see or hear.
- Swim only if it counts. Be certain of reaching a worthy goal (flotation, other people, shore.) Swimming sends warm blood to shoulders and limbs, greatly increasing heat-loss. In 10°C (50°F) water, hypothermia hits a "good" swimmer wearing a life-jacket after swimming only 1300 meters (1400 yards). In 0°C (32°F) water, 185 meters (200 yards) is the limit!

8. If you're in trouble, why does constant swimming, splashing and shouting often decrease your survival chances?

9. BEFORE VENTURING OUT TOO FAR FROM SHORE TRY THESE:

   a. Practice distress signals.

   b. Use the best attention-getter: CONTRAST.

   c. Why is emergency gear "international orange"?

   d. Learn to set off a flare.

CHOCOLATE & CHIPS
COCOA
Raisins

FUEL UP !

- Eat well regularly. Maintain an energy reserve with a balanced diet.
- For quick, ready energy, have frequent sugary snacks. Gorp, raisins, chocolate, and candy will keep up the body's heat-production without burning the reserve supply.
- Provide hot drinks to warm the inner core. Energy levels will benefit too, if drinks are healthful (soup, bouillion, broth, cocoa, tea with sugar, or hot fruit drinks.) Avoid too much coffee.
- Don't have alcoholic drinks. Alcohol gives a false impression of warmth by reducing shivering. Actually, surface blood vessels are relaxing, allowing more blood to circulate and cool more.

10. Traditionally, hypothermia victims were given brandy or rum to drink. Why was this a bad practice?

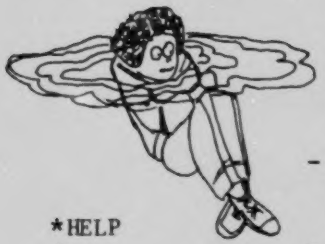
11. BEFORE VENTURING OUT IN WET WEATHER, HERE ARE SOME THINGS TO TRY:

   a. Test water-proof matches and match holders by dunking them in water. Then, in the rain or under a sprinkler, light a fire.

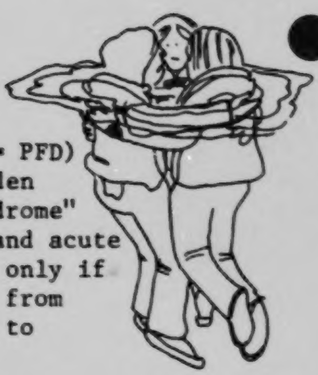
   b. Boil water for energy drinks.

*STAY AFLOAT !

- Put on a life-jacket (Personal Flotation Device = PFD)
- If forced to enter the water, go in slowly. Sudden immersion may cause "Immediate Disappearance Syndrome" with uncontrollable rapid breathing, dizziness, and acute pain. Surviving such cold shock may be possible only if wearing a PFD. Relieved of the struggle to keep from gulping water and sinking, the body has a chance to adjust to the cold.
- If forced to jump in, be prepared for cold shock. Increase buoyancy by pinching nose and holding breath, hopefully long enough to surface and control breathing.
- Once in, try to get out of the water and stick with the boat or a nearby floating object. Rig protection from any wind.
- If nothing floating is around, stick with other people. Form a HUDDLE.
- If alone, assume HELP.
- If not wearing a PFD, layers of clothing increase buoyancy. Blow down into front of jacket to improvise flotation. If possible, trap air in boots for buoyancy. Inflated pants make a float too.



*HELP
(Heat
Escape
Lessening
Position)



Huddle

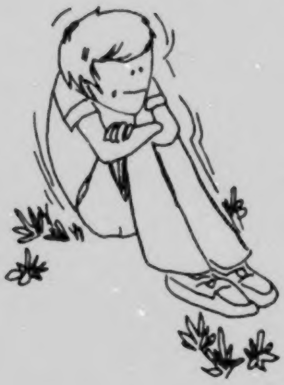
12. What is H.E.L.P.?

13. BEFORE VENTURING OUT ON THE WATER: YOU SHOULD DO THE FOLLOWING:
    a. Test different types of PFD's for buoyancy and warmth.
    b. Practice HELP and HUDDLE positions.
    c. Improvise flotation aids.

So....you've paid attention to all of the above and you're prepared. What kind of warnings should you look for once you're outside?

SYMPTOMS

If the inner core temperature deviates only 1°C (2°F), distress signals from the brain warn of the onset of trouble. Recognize the symptoms!



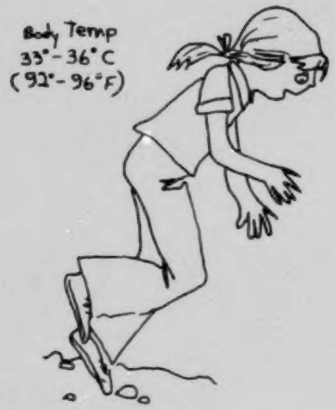
SHIVERING, COLD HANDS & FEET

Shivering is usually the first sign of possible hypothermia. The body is using bursts of energy in an effort to produce heat, but the heat loss goes on. "Cold hands mean a warm heart." The body constricts surface blood vessels to reserve warm blood for the inner core. Since the temperature of the extremities may drop to 4°C (40°F), without damage, frostbite is not necessarily associated with hypothermia. Symptoms of hypothermia demand treatment before symptoms of frostbite.

STOP! Recognizing and attending to these first symptoms may only require helping the victim put on dry clothes. Don't ignore the symptoms.

14. a. How should you treat shivering, cold hands and cold feet?

b. When should you treat shivering, cold hands and feet?

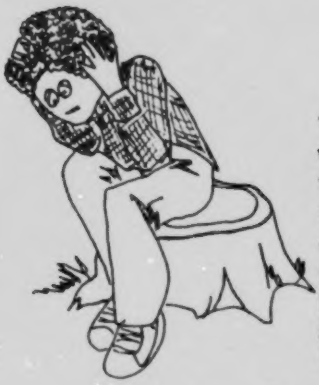


CLUMSINESS, LOSS OF DEXTERITY

As the limbs receive less and less warm blood, responsive movement becomes more and more difficult. Muscle control centers are also affected because less oxygen is transferred by cold blood in constricted blood vessels. The victim stumbles and fumbles. Along with growing numbness, the victim is unable to get going after a rest stop.

STOP! Don't believe a victim's claim of "I'll catch up. She really CAN'T. Find or rig shelter and start rewarming!

15. Stumbling and numbness are symptoms that can lead to severe hypothermia. What is the treatment for people suffering these symptoms?



LOSS OF REASON AND RECALL

The brain's thought control centers, starved for warm, oxygen-rich blood, start closing down. The victim acts careless and dazed. Responses may be inappropriate or show loss of memory. Speech is slow and slurred. Without reason, the victim may over-exercise, using up energy reserve to the point of collapse. Beyond caring, the victim may give in to conditions, dozing off without protection from the elements.

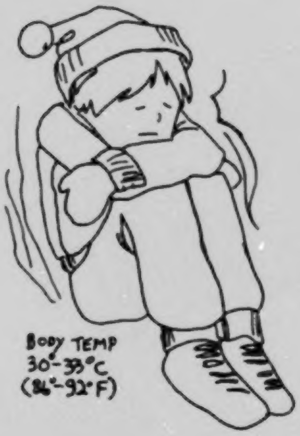
STOP! Don't believe victim's claims of "I'm okay." The victim really doesn't know better! Before it's too late, keep the victim awake and provide protection and heat.

16. What causes hypothermia victims to show loss of memory and slow, slurred speech?

SHAKING, MUSCULAR RIGIDITY

The exhausted body gathers futile and wasteful bursts of energy, at times shaking the victim violently. Since cold, slowly moving blood stagnates, body chemistry is altered and muscles become rigid. With a slow and irregular pulse, breathing is also erratic. Skin may appear discolored and feels very cold and puffy to touch.

BEWARE! Cold shock to vital organs, abnormally low blood pressure, and chemical imbalances may be fatal, even hours after warming treatment has apparently "cured" the victim. MEDICAL ASSISTANCE IS CRITICAL!!!

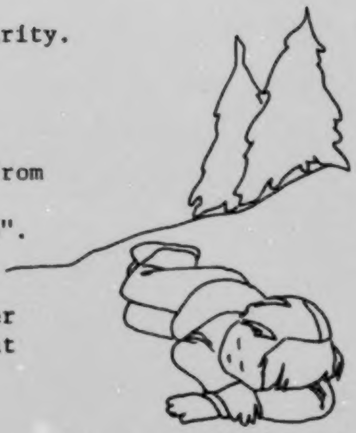


17. When the deep-body temperature reaches 30°-33°C (86°-92°F) shaking and muscular rigidity occur. What is required after you have succeeded in warming the victim?

▿COLLAPSE... DEATH

When the brain control centers fail, vital organs struggle on with increasing difficulty and irregularity. Breathing and heart beat finally stop. Lungs may hemorrhage, causing frothing at the mouth.

Begin warming treatment. Warm body core first. If arms and legs are heated first then cold blood from them rushes to the core. This cold blood causes a rapid drop in core temperature called "after drop".


BODY TEMP 25°-30°C (78°-86°F)

DON'T GIVE UP! Although fatal after-drop (a further lowering of body temperature after warming treatment has begun) is likely, don't assume death until the victim is warm and dead. MEDICAL ASSISTANCE IS IMPERATIVE.

18. Collapse...Things have gone too far at this point. The first three groups of symptoms of hypothermia are easily recognized and corrected. What are these first three groups?

a.

b.

c.

Of course, you'll never get hypothermia because you know how to protect yourself. But what do you do if you find someone else suffering from hypothermia?

TREATMENT

To provide selective and gradual warming is the simple treatment for raising lowered body temperature. Take care! Beware of after-drop.

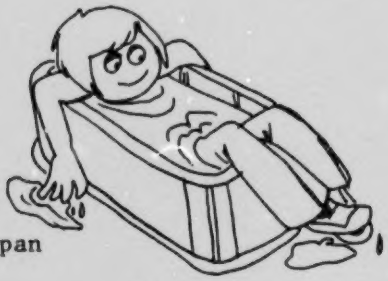
ALWAYS:

- Insulate victim against cold
- Protect victim from wind and wet
- Minimize movement of victim's body (even walking takes energy)
- Try to keep victim awake
- Keep victim's head low, feet up (get warm blood to head first)
- Beware of after-drop
- Protect victim from helicopter wind-chill
- SEEK MEDICAL ASSISTANCE

NEVER:

- Never leave victim without a heat-source
- Never massage or rub the victim (especially NOT with snow!)
- Never jostle the victim (such movement could cause heart stoppage)
- Never give alcohol
- Never give a sedative, tranquilizer, or pain reliever
- Never give up without medical advice

▾ WARM BATH



VICTIM: Must be conscious

RESCUER:
- Concentrate heat on trunk to prevent "after-drop"
- Start water at 20°C (70°F) raise to 42°C (110°F) (comfortable to elbow test) over 10 minute time span

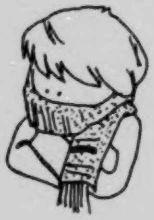
▾ HOT TOWELS

VICTIM: May be unconscious

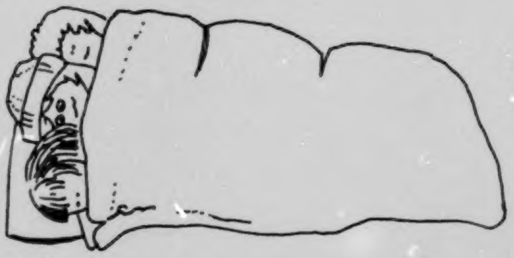
RESCUER:
- Wrap trunk (not limbs) in hot towels or blankets
- Keep warming with warmer water (like bath)
- Hot water bottle or wrapped, hot rocks OK too
- Beware of causing superficial burns

▾ WARM AIR

VICTIM: Must be handled GENTLY



RESCUER:
- Do not try to get the victim to swallow warm drinks
- Scarf over mouth and nose will trap warmth from exhaled air and pre-warm next breath
- Mouth-to-mouth resuscitation transfers warm air to victim (conscious or not)
- Special respirators provide warmed, moisture-laden air



▾ BUDDY-WARMING

VICTIM: Must be handled gently (conscious or not)

RESCUER:
- Remove all wet clothing (cut away to avoid jostling)
- Place victim on side in sleeping bag or blankets
- Warmth donor(s) should strip too
- Position donor(s) for direct skin-to-skin, heat transfer to front and back of victim

19. Why should you keep the victim's head low, and feet up?

20. Of the four warming techniques mentioned which ones may be used on unconscious victims?

21. What is meant by the saying "The best treatment for hypothermia is prevention"?

OCEAN WATERS IN MOTION: CURRENTS

TEACHER BACKGROUND - October 14

"October 14" continues the southward migration of our California gray whale. This section of the narrative, shows the gray whale dealing with various environmental factors. Your students are given a brief look at the breathing cycle, a look which may be expanded through the use of available films. Our whale also must deal with the currents faced in Umiak Pass and further south. The narrative provides a springboard for two activities dealing with currents: "Moving Right Along" and "Hot Air". As you embark on these activities, stress the effect of the physical world (the currents) on the biological world (the gray whale). Bulletin boards, films, records, etc. can help you tie these worlds together. The goal is to treat currents as they affect the life of the California gray whale.

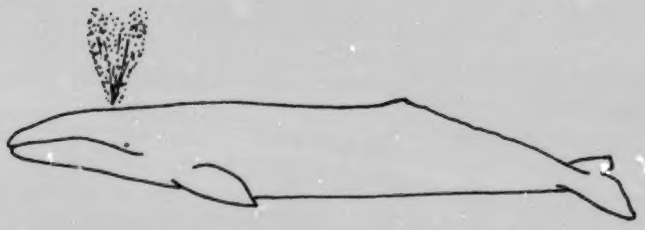
Duplicate the text pages. One set is recommended per student. This activity is best accomplished by individual students as homework or as an in-class assignment. As mentioned above, this material will benefit from supplemental audiovisual aids. At this point, you might consider posting a large scale map of North America on your bulletin board. On the map your students can show the route-to-date of the female gray whale. The route can be indicated by paper whales. Have your students indicate the calendar date on which the gray whales pass a point. They can easily do this by writing the date on the whales as they place the whales in the appropriate spots on the map. Upon completion of "October 14", plan to allow some time for a discussion of the narrative and to provide answers to the text questions.

KEY

1. a. Our whale spent eight minutes completing the breathing cycle described.
   b. She swam 7.5 cycles in one hour.
   c. She swam one-half mile in the cycle described.
   d. At this rate, she would swim 3.75 miles in one hour. (7.5 cycles x one-half mile).
   e. At this rate, she would swim 90 miles per day. (3.75 miles per hour x 24 hours.
   f. At this rate, she would have traveled 1260 miles since October 1st. (90 miles/day x 14 days).
   g. ~~Our whale's rate falls within the observed averages for distance~~ covered per day.
2. Since the halibut breathe through gills, they are unaffected by the rough water which made breathing difficult for our whale. The purpose of this question is to emphasize the fact that whales are air breathers and must come to the surface to breathe regardless of the weather.
3. The south flowing California current makes swimming easier for our gray whale as she moves south.

KEY WORDS

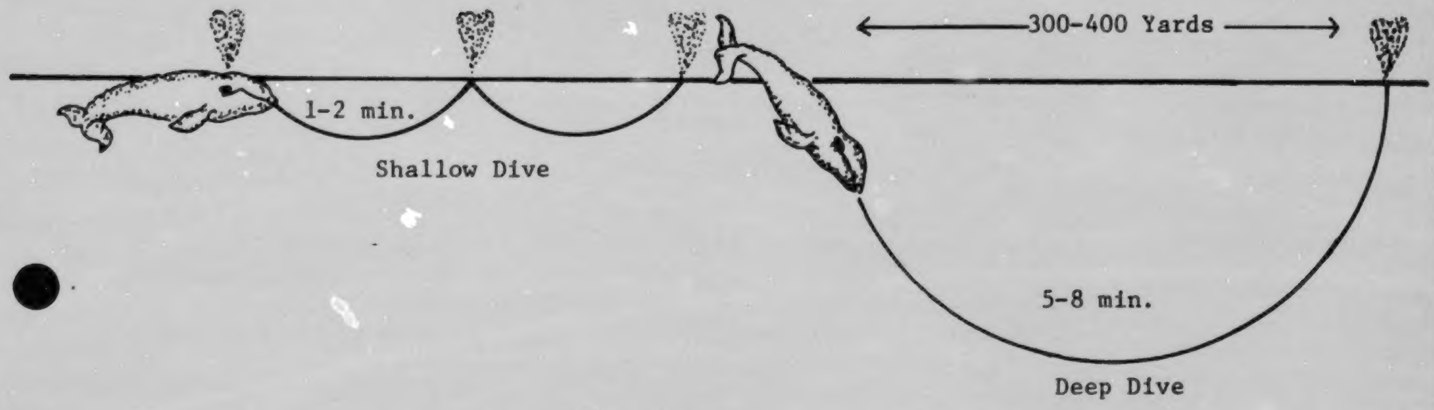
arctic
breathing cycle
current
exhales
flukes
impede
inhale
propel
rate
spout
stroke



OCTOBER 14

Swimming, breathing, swimming, breathing. Stroke after stroke her ten foot flukes push her 50 foot body through the cold Bering Sea.

The Breathing and Diving Rhythm
Of The Gray Whale



Her head breaks the water surface. Her blowholes open and a sudden rush of warm air escapes from her lungs. The expanding air cools into a cloud or fog called a spout. She inhales and shallowly dives disappearing beneath the surface for one minute.

She resurfaces, exhales, inhales, and dives shallowly again. After another minute, she again resurfaces, exhales and inhales.

She dives deeply, throwing her flukes out of the water to help propel her downward. She swims aggressively forward for six minutes before resurfacing and beginning the breathing cycle again. During this cycle of three breaths she has moved another half mile southward.

1. a. How much time did our whale spend in completing the breathing cycle described above?

_____________minutes.

b. How many cycles did she swim in one hour(60 minutes)?

_____________cycles.

c. How far did she swim during the cycle?

_____________miles.

d. If she kept swimming at this rate how far would she swim in one hour (60 minutes)?

_____________miles.

e. At this rate how far would she swim in one day (24 hours)?

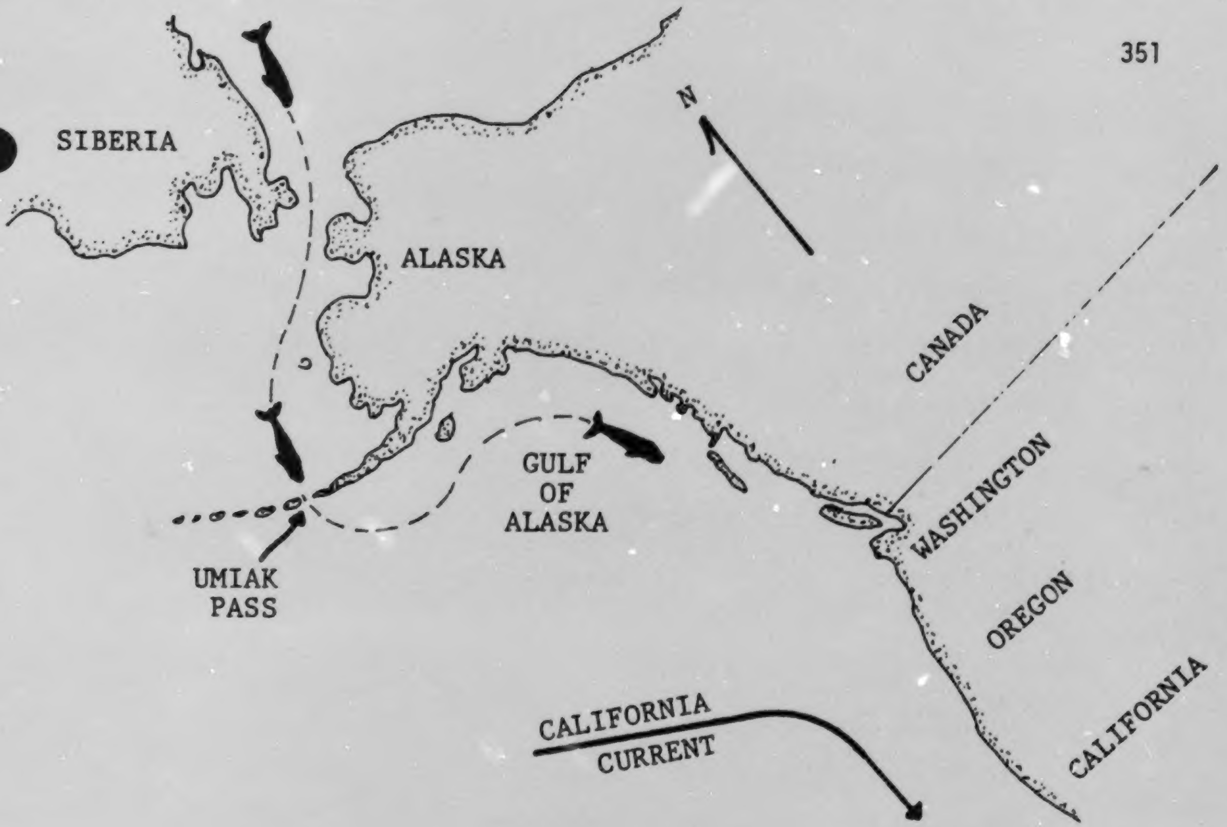
_____________miles.

f. At this rate how far has she traveled since October 1st?

_____________miles.

g. Gray whales are known to swim 85-100 miles per day during the long swim. How is our whale doing compared to the average?

Swimming, breathing, swimming, breathing. Night and day for the next week, she moves southeastward toward Umiak Pass. Umiak Pass is the first break in the chain of Aleutian Islands. As she approaches the pass, our gray whale is joined by still more grays. Together they swim south and east.


SIBERIA
ALASKA
N
CANADA
GULF OF ALASKA
WASHINGTON
UMIAK PASS
OREGON
CALIFORNIA
CALIFORNIA CURRENT

The wind and snow come more often. Winds from the north lash the waters of the Umiak Pass. The churning water makes breathing difficult for our gray. Her powerful flukes drive her on. Strong currents run through the Umiak Pass. Swimming, breathing, swimming and breathing, she passes into the Gulf of Alaska.

2. Why didn't the stormy water which made breathing difficult for our whale have an effect on the breathing of halibut fish in the pass?

For the next three weeks, she swims through strong currents. At times, the currents aid her progress south. At other times the strong currents impede her progress. The currents move vast quantities of water. Swimming and breathing she moves toward the southflowing California Current. The California Current carries cold arctic water. This cold water influences life in the oceans and on the land.

3. How might the California Current aid our whale in her southward swim?

TEACHER BACKGROUND - Moving Right Along and Hot Air

Ocean circulation has been used by man for many years. Currents have aided sailors since before the written word. More importantly ocean circulation shapes climate and influences plant and animal populations on land as well as in the ocean.

"Moving Right Along" and "Hot Air" provide your students with an opportunity to create currents. In the process they will be exposed to several of the factors that cause ocean currents. Perhaps because currents are not readily visible, students often have difficulty understanding currents. The following activities look at currents caused by density differences and wind. You may wish to provide general current descriptions through films or posters. The following demonstration can be used as an effective introduction to currents. Add water to a 5 or 10 gallon aquarium until it is half full of clear tap water. Have ready:

a) 400 ml beaker of ice water to which 5 drops of blue food coloring and 1 tablespoon of salt have been added (stir until all of the salt is dissolved).

b) 400 ml beaker of HOT water to which 5 drops of yellow food color have been added.

Follow the procedure below:

1. Have a student slowly pour the cold water into one end of the tank.
2. Simultaneously, have a second student slowly pour the hot water into the other end of the tank.
3. Have your class observe the tank (preferably from eye level).

The two added waters will form distinct layers, the less dense hot water will form a yellow band on the surface. The more dense blue, ice water will form a layer on the bottom. This graphic demonstration of the effect of density on water movement can lead into your discussion of currents. Cold water produced in the arctic as icebergs melt or form sinks and moves away from the poles. Water warmed in the tropics moves as surface currents away from the warm middle-latitudes. In general, currents that flow from the equator are warm. Currents that flow from the poles and toward the equator are cold. Conclude by asking your students which type of currents the gray whale is most likely to confront during the early stages of her long, southerly, swim from the Bering Sea. Since she is moving south toward the equator, most students will agree that cold currents (blue water) are the type our gray whale will encounter.

"Moving Right Along"

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished by small groups. Clear wash trays or shoe storage boxes work best for the oceans. The activity provides three different situations. It is possible to complete all three in a single lab period. Caution your students to let the tub waters settle and to remove the straight pins as gently as possible to minimize turbulence. For convenience, a data sheet is provided for recording the results. Upon completion, allow time for a discussion of the concepts involved in the activity. During your discussion be sure to provide the answers to the questions found in the "Analysis and Interpretation" sections.

"Hot Air"

Duplicate the activity pages. Again, one set is recommended per student. This activity is best accomplished by pairs or small groups. Glass baking dishes or similar shallow, clear trays are best for this activity. The ocean containers used in "Moving Right Along" will work, although with less than perfect results. The deeper containers make bottom counter currents more difficult to see. The island placement is also more difficult. This activity can result in water spills so have plenty of paper towels available for your students. Conclude the activity with a discussion of the questions in the "Analysis and Interpretation" sections. During your discussion emphasize the effect of currents on the life of the gray whale.

KEY

"Moving Right Along"

Analysis and Interpretation - The Duwamish River and Puget Sound

1. While the answer depends upon experimental results, the six minute temperatures for the surface, middle, and bottom should show little difference from the starting temperatures.
2. a. The answer depends upon experimental results. In general, the freshwater currents from the cup should be above the level of the pinhole.
   b. Freshwater is less dense than saltwater.
3. a. Since freshwater is less dense than salt water, the best sample of freshwater would be taken at the surface.
   b. The best sample of saltwater would be taken from the bottom.
4. Winter rains cause a large inflow of freshwater. As shown in the experimental results, the freshwater floats on top of the salt water. A surface sample would, therefore, be a freshwater sample.

Analysis and Interpretation - California Current and Equatorial Counter Current

1. a., b., c. Answers depend upon the experimental results.

Analysis and Interpretation - California Current and Southern Waters

1. Answer depends upon the experimental results.
2. a. Upwelling provides nutrients needed for the growth of phytoplankton. As such, upwelling increases plankton growth.
   b. Upwelling indirectly provides the stimulus for increased fish fish population growth. Increased plankton numbers provide increased food for plankton-feeding fish and so on up the food chain.
   c. Areas of upwelling would, indeed, be good places for young gray whales to feed because of the abundance of food organisms. Some scientists attribute whale migrations, at least in part, to food availability.

3. Cold waters tend to [✓ *sink*] / *float* when they meet warm waters. (Circle the correct answer)
4. Freshwaters tend to *sink* / [✓ *float*] when they meet saltwaters. (Circle the correct answer)
5. a. Currents may be caused by differences in density caused by
      _______ A. differences in temperature
      I B. differences in salinity
      II, III C. differences in temperature and salinity
   b. The conditions described by your students will vary. In general, the experimental conditions would have water of the same salinity but different temperatures in the cup and tray.
6. Currents have many effects on gray whales. Those mentioned in the text are:
   a. aiding swimming
   b. hindering swimming
   c. alteration of food availability

KEY

"Hot Air"

Analysis and Interpretation -I:

1. Generally, the drawings will be different. The surface currents move away from the wind while those at depth move back toward the source.
2. The currents move most rapidly at the source of the wind.
3. The current spreads out as it moves away from the wind source.

Analysis and Interpretation - II:

1. The island causes the current to split and form two currents.
2. The current is stronger in front of the island. This is a good opportunity to introduce the concept of windward and lee sides of islands.

Analysis and Interpretation - III:

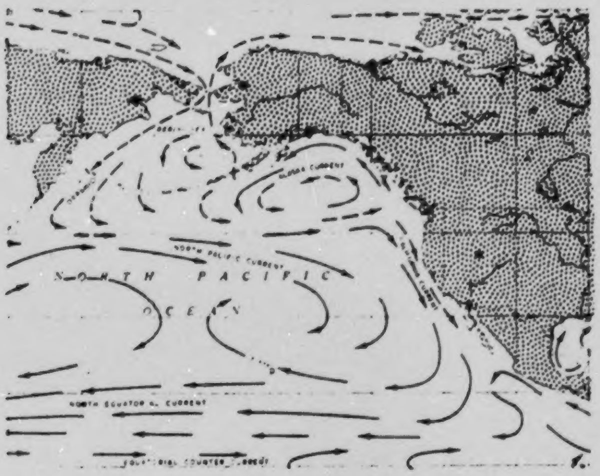
1. The surface currents move across the submerged island with only a small amount of disturbance. The currents at depth are greatly affected by the presence of the island.
2. a. The submerged islands cause the ocean currents to become confused and turbulent.
    b. The gray whale is helped along in its migration when the currents flow in its direction of travel. It is hindered when it must swim against the currents to proceed.

Analysis and Interpretation - IV and Summary:

1. The currents are more complex with odd-shaped objects. The dye movement clearly shows the places where moving waters collide.
2. The currents do not always move in the direction of the wind. Factors such as islands, land masses, and depth of water influence the direction of movement.
3. a. The bottom currents differ from the surface currents in their speed and often in the direction in which they move.
    b. One possible source of the differences is the presence of islands or other land masses.
4. Two environmental factors mentioned earlier which can cause currents include:
    a. the rotation of the earth
    b. differences in density of ocean waters due to differences in temperature and/or salinity.
5. Two ways in which currents affect the life of the California gray whale include:
    a. aiding or hindering swimming
    b. increasing or decreasing food supply and availability

KEY WORDS

alternately
complex
currents
dense
density
docks
duplicate
environmental
equator
flow
generate
hinder
influence
nutrient-rich
observation
salinity
submerged
upwelling


NORTH PACIFIC CURRENT
NORTH PACIFIC OCEAN
ALASKA CURRENT
NORTH EQUATORIAL CURRENT
EQUATORIAL COUNTER CURRENT

MOVING RIGHT ALONG

What causes the currents that sometimes help, sometimes hinder the California gray whale? What forces can move enough water to slow the progress of a twenty ton swimmer? In the following activity you will observe some of the environmental factors which may cause movement of ocean waters. You will also have a chance to observe what happens when different ocean currents meet.

Materials:

plastic wash tray or similar container (preferably clear)
food coloring (2 colors)
paper cups (2)
straight pins (2)
salt
thermometer
measuring spoons (¼ teaspoon, ½ teaspoon, 1 teaspoon)
ice cubes
plastic ruler
tap water

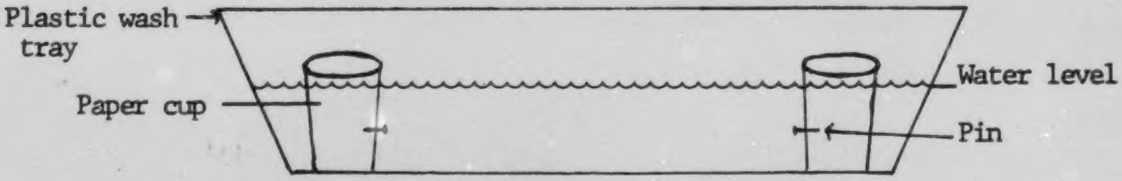
PUGET SOUND
WASH.
OREGON

Procedure:

Part I - The Duwamish River and Puget Sound, Washington

The Duwamish River flows into the saltwater of Puget Sound at Seattle. Puget Sound flows into the Pacific Ocean. In this part of the activity you will duplicate the conditions found where these waters mix.

1. Obtain two paper cups and a plastic wash tray. The cups will generate the river currents. The plastic wash tray will be Puget Sound.
2. Fill the two paper cups with cold tap water. Add two drops of food color to each cup.
3. Obtain two straight pins. Midway between the top and the bottom, stick one pin in each cup. LEAVE THE PIN IN THE CUP.
4. Place one cup at each end of your plastic wash tray.
5. Place 1 teaspoon of salt in your wash tray. Fill your tray with cold tap water to a depth one-half inch below the top of the cups. Your set-up should look something like the drawing below.



6. Obtain a thermometer and measure the temperature of the tray water at the surface, middle and bottom. RECORD the temperatures on your Data Sheet.
7. Wait until the water in the tub has settled down (at least 60 seconds). Then CAREFULLY pull out the two pins. Try NOT to disturb the water.
8. Observe the small current that is generated. As you observe, record the surface, middle, and bottom temperatures in areas where the current settles. Record these temperatures at 2 minutes, 4 minutes and 6 minutes.
9. After 6 minutes record the level of currents from the bottom up. Compare the level of the currents to the level of the pinhole. RECORD this information on your Data Sheet.

Analysis and Interpretation - The Duwamish River and Puget Sound

1. How did your six minute temperatures for the surface, middle and bottom compare with your starting temperatures?

2. a. How did the level of your currents (after 6 minutes) compare with the level of the pinhole?

2. b. Is freshwater more or less dense ("heavy") than saltwater?

3. As a research scientist, you're interested in obtaining water samples. You wish to sample Puget Sound at the mouth of the Duwamish River.

   a. At what depth would you expect to get the best sample of fresh water?

   b. At what depth would you expect to get the best sample of salt water?

4. During the winter, surface water taken from docks at the mouth of the river is almost entirely freshwater. How do your experimental results help explain this observation?

Part II - The Cold California Current and The Warm, Salty Equatorial Counter Current.

The cold California Current flows south along the west coast of Canada and the United States. It runs into the warm, salty Equatorial Counter Current near the equator. In this part of the activity you will duplicate the conditions found where these currents mix.

1. Repeat steps 1 to 10 of the procedure for Part I with the following changes.
   a. California Current - water in cup cooled to 6°C
      plus ¼ teaspoon salt in cup
      and two drops of food coloring.
   b. Equatorial Counter Current - water in cup at 20°C
      plus ½ teaspoon salt in cup
      and 2 drops food coloring
      (different color).
   c. Pacific waters - add 1 teaspoon of salt to tray
      and fill with cool tap water.
2. RECORD your observations on the Data Sheet.

Analysis and Interpretation - California Current and Equatorial Counter Current

1. Use your temperature and level data to answer the following questions.

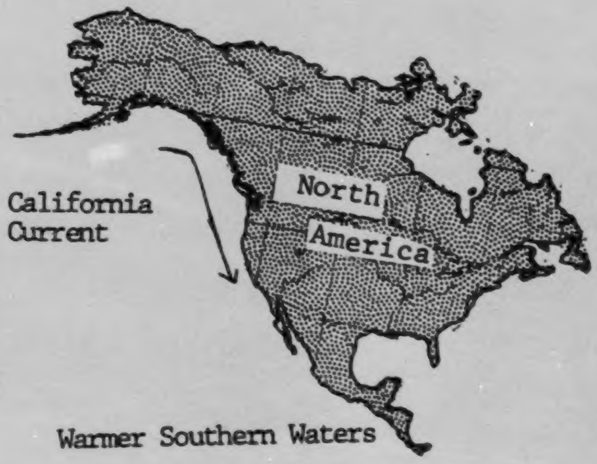
   a. Where did the cool California current flow?

   b. Where did the warm, salty Equatorial Counter Current flow?

   c. Cold water is more dense than warm water. Salty water is more dense than freshwater. Cold water and salty water tend to sink.

      Was the cold California Current more or less dense than the warm, salty Equatorial Counter Current? Please explain your answer.

Part III - The Cold California and Warmer Southern Waters



The cold California current flows south along the Canadian and U.S. west coast. It mixes with warmer waters off of Mexico.
The California Gray whale swims southward in this current.

1. Repeat steps 1 to 10 of the procedure for Part I with the following changes.
    a. Cold California Current - water in cups cooled to 2°C plus ¼ teaspoon salt in cup and two drops of food coloring.
    b. Warmer Southern Waters - Add 1 teaspoon of salt to tray and fill with 10°C water.
2. RECORD your observations on the Data Sheet.

Analysis and Interpretation - California Current and Southern Waters

1. Where did the cold California current flow?

2. The southward movement of the California current may cause upwelling. Upwelling brings nutient-rich water from the ocean bottom to the surface.

    a. What is the effect of upwelling on plankton growth?

    b. What is the effect of upwelling on fish population?

    c. Would areas of upwelling be good places for young gray whales to feed? Please explain.

3. Cold waters tend to sink / float when they meet salt waters. (Circle the correct answer)

4. Freshwaters tend to sink / float when they meet salt waters. (Circle the correct answer)

5. The three statements below are true. The activities you performed help support two of the statements. In the blank in front of the statements, write the number of the part of the activity that helps prove the statement.

   a. Currents may be caused by differences in density caused by

      ____ A. differences in temperature.

      ____ B. differences in salinity.(amount of salt in the water)

      ____ C. differences in temperature and salinity.

   b. In the space below describe experimental conditions that would help prove the unsupported statement from part a.

6. What is one effect that currents have on gray whales?

DATA SHEET

Duwamish/Puget Sound Temperatures

	Start	2 Minutes	4 Minutes	6 Minutes
Surface				
Middle				
Bottom				

After 6 minutes: Level of pinhole________cm.

Level of currents_______cm.

California Current/Equatorial Counter Current Temperatures

	Start	2 Minutes	4 Minutes	6 Minutes
Surface				
Middle				
Bottom				

After 6 minutes: Level of pinhole ______cm.

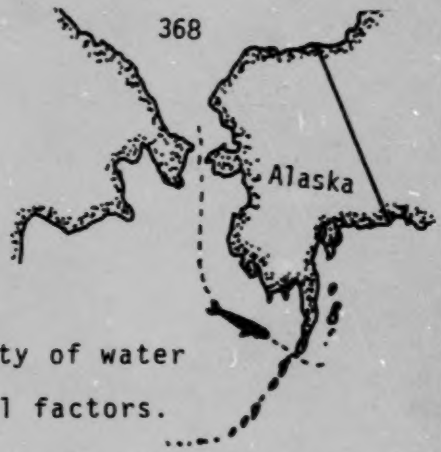
Level of currents _____cm.

California Current/Southern Waters Temperatures

	Start	2 Minutes	4 Minutes	6 Minutes
Surface				
Middle				
Bottom				

After 6 minutes: Level of pinhole ______cm.

Level of currents _____cm.



HOT AIR

Differences in the temperature and salinity of water can cause currents. So can other environmental factors. California gray whales swim through Umiak pass in the Aleutian Islands. As the gray whales approach the narrow pass, the winds whip the water. The winds move the water into storm waves. Winds blowing for very long periods of time also cause currents. In the following activity you will have a chance to observe wind-caused currents.

Materials:

glass baking dish or other clear tray
food coloring
water
finger bowl
hot air
assortment of waterproof objects

Procedure I:

1. Obtain a glass baking dish or other clear tray. Fill the tray with water. Let the water settle completely.
2. Place a drop of food color at one end and blow gently across the tray. In the space below, draw what happens at:
   a. The surface -

   b. On the bottom -

Analysis and Interpretation - I:

1. Are your drawing different? If so, how do they differ?

2. Where do the currents move most rapidly?

3. What happens to the current as it moves away from the wind source?

Procedure II:

1. Place the finger bowl in the center of the tray to represent an island.

2. Add a drop of food coloring and supply the necessary wind. In the space below, draw what happens to the food coloring in front and in back of the island.

Analysis and Interpretation - II:

1. What effect does the island have on the current?

2. Is the current stronger in front of or behind the island? How can you tell?

Procedure III:

Repeat the procedure in Part II except for the following. Use a submerged petri dish to represent a submarine island. In the space below, draw what happens to the food coloring.

Analysis and Interpretation - III:

1. How do these results differ from those obtained in Part II?

2. The Aleutian Island chain has many submerged islands.
    a. What effect do these islands have on the currents?
    b. How might a California gray whale swimming in Aleutian waters be alternately helped then hindered by currents?

Procedure IV:

1. Again, repeat the precedure in Part II with the following change. Instead of a finger bowl, use a waterproof object with an irregular shape.

2. In the space below, draw what happens to the food coloring.

Analysis and Interpretation IV and Summary:

1. Were the currents more or less complex with your odd-shaped object? Please explain.

2. Do the currents always move in the direction of the wind? If not, what factors might influence the direction of movement?

3. a. How do the bottom currents differ from the top currents?

   b. What is one possible source of the differences?

4. Wind can cause currents. What are two other environmental factors that can cause currents?

   a.

   b.

5. What are two ways in which currents affect the life of the California gray whale?

   a.

   b.

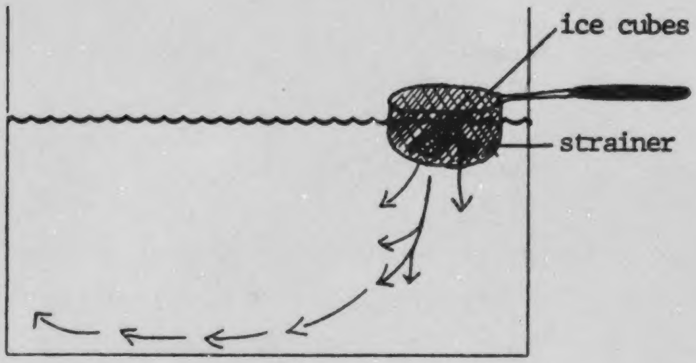
TEACHER BACKGROUND - November 1
The Hydrometer
Heating It Up
Ol' Sea Salt
Currents: A Case Study

"November 1" serves as the introduction to several activities dealing with currents. The idea of rivers of moving water within the oceans will be foreign to many of your students. The forces which set up the currents are likely to be even less familiar. "November 1" provides information relating to currents caused by differences in density, the earth's rotation, and wind. Density differences due to temperature and salinity are discussed and provide the background necessary for "The Hydrometer", "Heating It Up", and "Ol' Sea Salt".

Through the activity "The Hydrometer" your students will construct simple hydrometers with which they will measure the density of various solutions. These same hydrometers are used in "Heating It Up", an activity dealing with the effect of salinity on the density of water. These three activities provide your students with some "hands-on" experiences with the factors that cause ocean currents. The "Analysis and Interpretation" sections endeavor to relate the activities to the situation obtaining in the oceans. It is often difficult for students to see that the forces which they observe on a small scale in the laboratory are sufficient to cause the vast movement of water seen in the oceans. As you work through and discuss the activities, stress that the forces are, indeed, the same.

The following activities can be beneficially supplemented with audio-visual materials. Several eye catching demonstrations may be used to introduce the concept of water density. For example, an effective demonstration of the manner in which very dense water is formed in oceans can be staged quite easily.

Use ink or food coloring to make some colored ice cubes. Place the cubes in a luke warm "ocean" in an aquarium or other transparent tank and observe the movement of cold blue water from the melting ice down to and along the bottom of the "ocean." The effect is best if the ice cubes are confined to one end of the tank by means of a wire strainer or cage.



In your discussion point out that this represents an ideal situation. Within the actual basin there will be the effects of the topography and to some extent the Coriolis effect. Although the winds act only on the surface layer of water, they can indirectly set in motion large-scale vertical and horizontal water motions.

A slightly different, but effective, demonstration may be done as follows: Fill a 5 or 10 gallon aquarium tank half full with clear tap water.

Have ready:
- a) 400 ml beaker of ice water
  add 1 tablespoon salt
  blue color (stir until all salt is in suspension)
- b) 400 ml beaker of HOT water
  no salt
  yellow color

The procedure is as follows:

1. Have one student pour dense, cold water into one end of the tank.
2. Have another student pour hot, less dense water into the other end of the tank.
3. Have students observe (from eye level, if possible).

If the pouring is done carefully a nice, three color tank is the result. Relate the results to the layering seen in the oceans and the movement of waters caused by different densities.

Duplicate the activity pages. One set is recommended per student. "November 1" and "Currents: A Case Study" are best performed by individual students as an in-class or homework assignment. You may elect to have your students meet in small groups to discuss their answers before you provide the answers to the text questions during a general class discussion. As always, use the approach that will work best with your particular class.

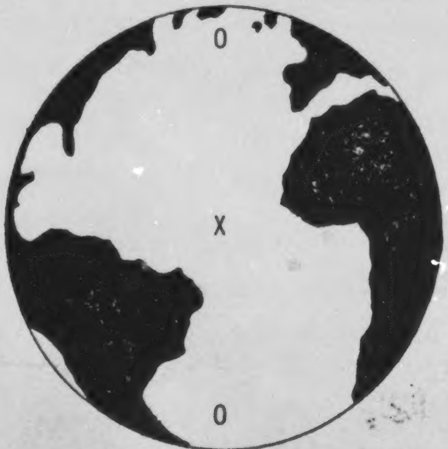
"The Hydrometer", "Heating It Up", and "Ol' Sea Salt" are laboratory activities best performed in pairs or small groups. The hydrometer construction is straight-forward. Demonstrate how to safely insert the number of students per group. For example, tall, thin jars may be used instead of graduated cylinders. It is possible to run these three activities on consecutive days with a general follow-up discussion after all three have been completed. Alternatively, discussions after the complettion of each of the activities and before commencing the next activity helps insure that your students are"on the right track" before proceeding to the next activity. The abilities of your class will determine the strategy you employ.

It is helpful to have a completed hydrometer on display during "The Hydrometer". Distilled water serves as the "standard water" for calibration. A refresher in hydrometer calibration can serve as a fitting introduction to "Heating It Up" and "Ol' Sea Salt". "Heating It Up" is a good time for a refresher course in laboratory safety and fire extinguisher location. Suggested solutions for "Heating It Up" are: solution A = 3.5% NaCl (A 3.5% NaCl solution may be made by adding 35 grams of NaCl to 1000 ml of distilled water); solution B = 5% NaCl and solution C = 1% ethyl alcohol.

KEY

November 1

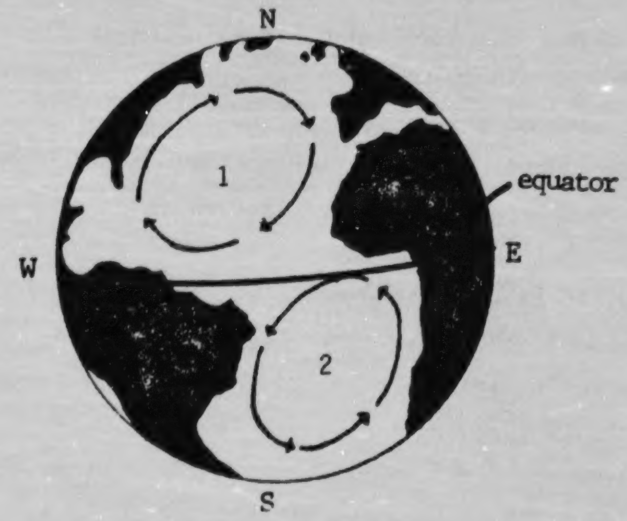
1. A "river" of water within the sea is called a current.
2. One force that moves ocean waters is the direct rays of the sun which provide more heat to the seas near the equator. Warm topical seas expand, rise and move away from the equator.
3. The world map below is correctly marked:



4. [✓ *Saltwater*] / *freshwater* is more dense ("heavier"). Circle the correct answer.

5. The deepest water in the oceans is *warm* / [✓ *cold*] and *"light"* / [✓ *"heavy"*]. Circle the correct answers.

6. The map below is correctly labeled:



7. Three factors important in causing currents are:
   a. differences in density of the water
   b. the earth's rotation
   c. wind

8. Three ways in which currents affect living things may be chosen from the following:
   a. hinder or facilitate movement
   b. determine where plants and animals can live
   c. determine the course of ships
   d. affect the migration and settling of people
   e. affect the climate of the land near which they pass.

The Hydrometer

1. Solution B (5% NaCl) has the greatest amount of salt in the water.
2. Solution A (3.5% NaCl) is most likely sea water.
3. Answers will vary depending on the length of the card in the glass tube. Recall that each line represents a density change of .001 g/ml.

4. The densities of the hypothetical solutions are as follows:

A. 1.000 g/ml

B. 1.004 g/ml

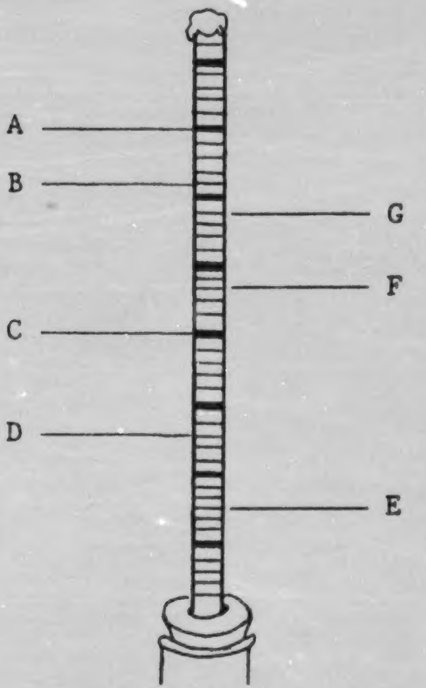
C. 1.015 g/ml

D. 1.022 g/ml

E. 1.028 g/ml

F. 1.012 g/ml

G. 1.006 g/ml



5. Ocean water with the greatest density is found at the greatest depths. This question relies on information found in "November 1" or on deductions made by your students from the information in "The Hydrometer".

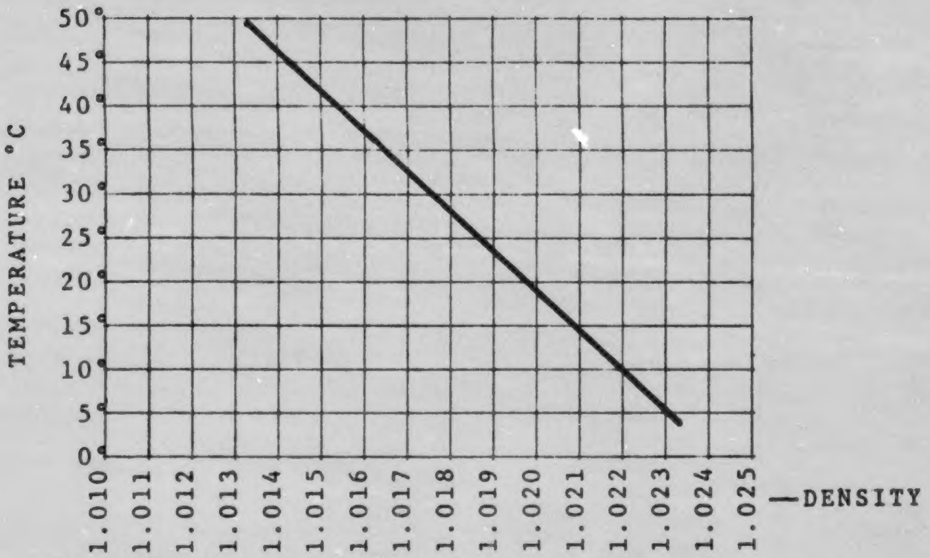
6. a. The approximate density of melting polar ice is 1.000 g/ml.

   b. The approximate density of seawater near ice that is beginning to form is something greater than 1.025 g/ml. This question relies on information found in "November 1" and is designed to provide continuity between activities.

Heating It Up

1. The plotted experimental data should resemble the graph below:

TEMPERATURE VS DENSITY



2. As sea water is warmed, the density decreases. As it is cooled, the density increases.
3. The warmest sea water would be found in the warmest areas, i.e. at the surface and near the equator. The coolest sea water would be found at the greatest depths in the ocean.
4. Considering temperature alone, the least dense sea water would be found at the surface, the most dense at the greatest depths.
5. Answers will vary depending upon the experimental results. Some approximations follow:

TEMPERATURE	DENSITY
25°C	1.018 - 1.019
35°C	1.016 - 1.017
45°C	1.014 - 1.015

6. As fully loaded ships from Indonesia move toward Washington, they encounter colder, more dense water. Just as the hydrometer floats higher in more dense water, so will the ship. The ship behaves like a giant hydrometer.

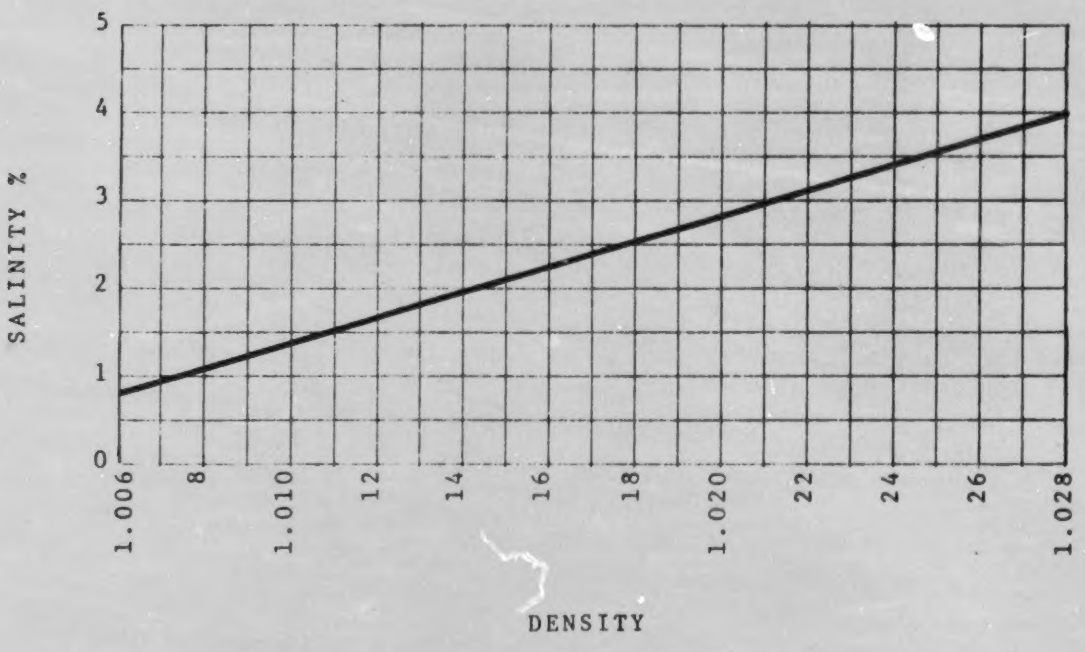
Ol' Sea Salt

1. The data table will vary according to experimental results. Some approximate results follow:

Solution	Density
4%	1.028 g/ml
2%	1.014 g/ml
1%	1.006 g/ml

2. The plotted experimental results should resemble the graph below.

SALINITY vs. DENSITY



3. Following the line of reasoning developed in the procedure your students should be able to conclude that 50 ml or 1% solution plus 50 ml of water would yield a .5% solution. From the graph, the predicted salinity of the solution would be about 1.004 g/ml.

4. From the above graph, the density of a 3% solution would be about 1.021 g/ml

5. From the graph, the average salinity of sea water with a density of 1.025 g/ml would be about 3.5%.

6. Because river water is fresh, it is less dense than the sea water and will float on top of the sea water.

7. Deep ocean water is saltier than surface water because salty, dense water sinks.

8. a. The waters with the lowest salinity would be found near the surface and in the warmest areas.

   b. The waters with the highest salinity would be found in the cold deep oceans.

9. We call the movement of dense ocean waters to areas of less dense water "currents".

Currents: A Case Study

1. El Niño is a weather-related change in ocean currents.

2. El Niño causes a drastic drop in anchovy catches.

3. The Peru Current and the Humboldt Current are one in the same and should be so labeled on map 1.

4. One factor which helps cause the decrease in water density seen when El Niño arrives is the increase in surface water temperature. In "Heat It Up" your students were acquainted with the effect of temperature on water density.

5. The "Callao Painter" is caused by hydrogen sulfide gas released by the break-down of dead animals and plants.

6. Three major Peruvian industries that are affected by El Niño include:

   a. fishing

   b. fertilizer

   c. tourism.

7. El Niño results in higher chicken prices because fishmeal made from Peruvian anchovies is used in chicken feed. A reduction in anchovies causes an increase in the price of chicken feed. The price increase is passed on from the farmer to the consumer and is reflected in higher prices for the chicken in your market.

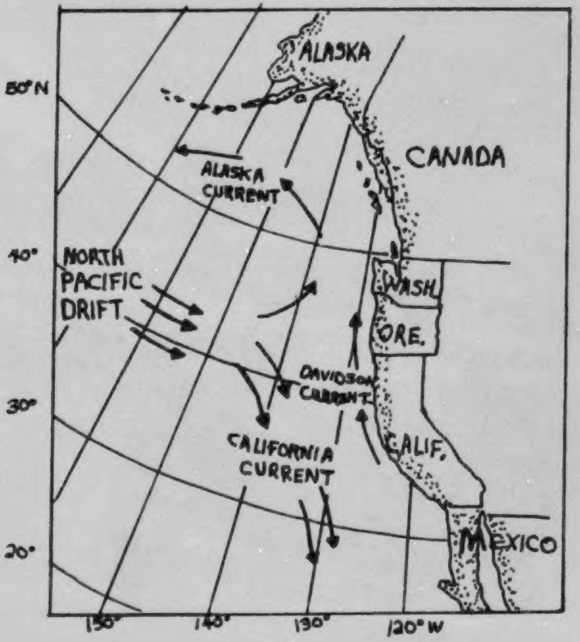
KEY WORDS

adjustment
anchovy
approximate
average
axis
calibrated
Callao Painter
carcasses
climate
course
current
data
density
dissolved
economy
El Niño
equator
estimate
evaporation
expand
fertilizer
fishmeal
force
global
graduated cylinder
guano
gyres
hinder
horizontal
hydrogen sulfide
hydrometer
migration
nutrients
phenomenon
plot
polar
pole
predict
protein
rays
rotation
salinity
solution
"standard water"
upwelling
veer
vertical
weakened

NOVEMBER 1

The fog shrouded waters begin to churn. Wind from the north increases the size of the ocean waves. Breathing becomes more difficult for our gray whale. The tops of the waves break into icy spray. Through the fury of the storm she swims south and east. Swimming becomes more of an effort as she moves head-on against the Alaska Current. For the next three weeks, our gray whale will be swimming "upstream" in a giant river within the ocean - the Alaska Current. What are these currents? What causes them?

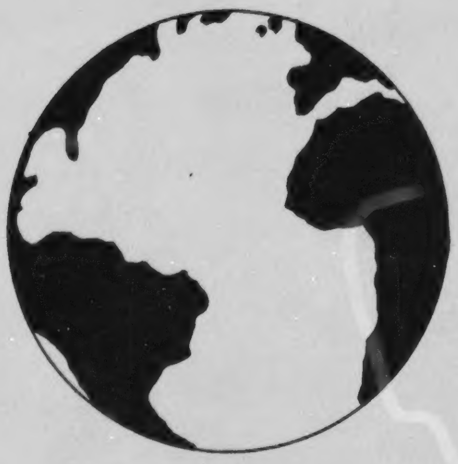
1. What do we call a "river" of water within the sea?


ALASKA
50°N
CANADA
ALASKA CURRENT
40°
NORTH PACIFIC DRIFT
WASH.
ORE.
DAVIDSON CURRENT
30°
CALIF.
CALIFORNIA CURRENT
20°
MEXICO
150°
140°
130°
120°W

The waters of the sea are always going somewhere. The water splashing off the back of our gray whale may have arrived from the coast of Japan after a 5,000 mile trip. Several forces act to move ocean waters. As the earth moves through space it spins on its axis in such a way that the seas near the equator receive the direct rays of the sun. These direct rays provide more heat to the seas near the equator. Polar seas receive fewer warming rays. The warm tropical seas expand, rise, and flow away from the equator. Cold, heavy polar waters sink and flow toward the equator.

2. What is one force that moves ocean waters?

3. On the world map below, the white areas show water.
   a. Place an X where the warmest waters would be found.
   b. Place an O where the coldest waters would be found.



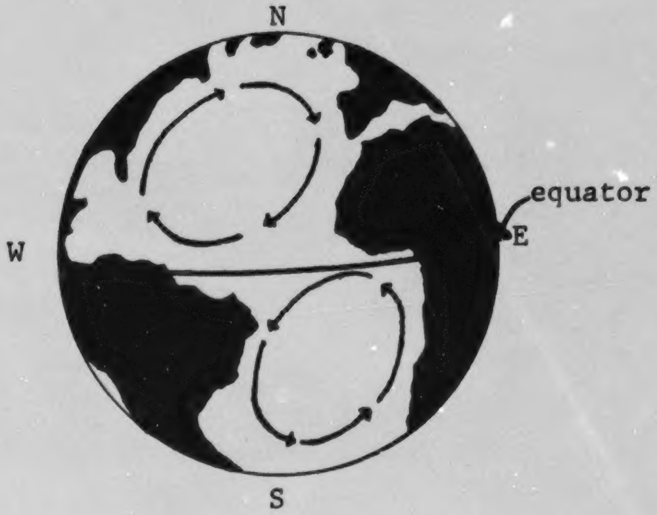
So, Currents can be caused by differences in the density (heavy or light) of water. We have seen that cold water is heavier than warm and tends to sink. Salt, too, can make water heavy. Sea water contains salt. Usually the proportion of salt in the open sea stays close to 3.5 percent. This means that every 100 grams of sea water would contain about 3.5 grams of salt. There are, however, some exceptions to this rule. For example, near melting polar ice the seawater tends to be less salty because the ice that is melting is nearly fresh.

4. Saltwater / freshwater is more dense ("heavier"). Circle the correct answer.

Water that is near ice that is beginning to form has more than the average amount of salt. There is more salt because as the ice freezes, it leaves extra salt behind in the water. The extra salt makes this water more dense (heavy) and it sinks.

5. The deepest water in the oceans is warm / cold and "light" / "heavy". Circle the correct answers.

The rising of warm, less salty waters and the sinking of cold, more salty waters plays a major role in causing currents. These movements of water should tend to produce rivers of water in straight lines. A look at our current map shows that this isn't the case. The major currents flow in circular patterns called gyres. These circular patterns are due to the spinning of the earth on its axis. The spinning causes the water to veer (move at an angle) slightly to the right in the northern half of the world. Spinning also causes the water to veer slightly to the left in the southern half of the world.



6. On the map above:

    a. Place a number #1 on a gyre moving to the right, north of the equator

    b. Place a number #2 on a gyre moving to the left, south of the equator.

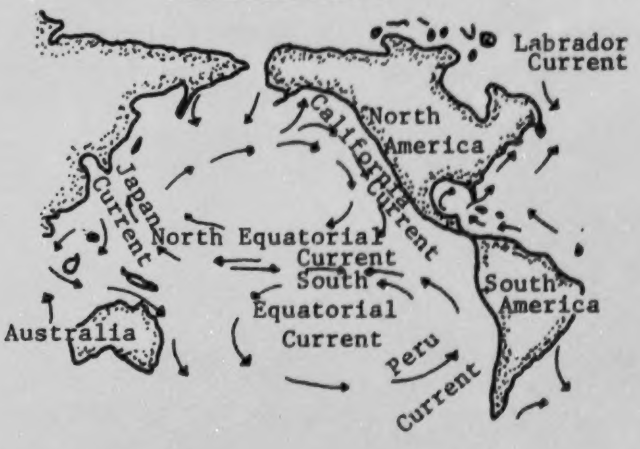
Another equally important factor that produces movement of the water is wind. The air at the equator, as we have seen, is warmer. The warm air expands, grows lighter, and rises. As it reaches the poles, it cools. the cool air then sinks back to the earth and the cycle begins again. As the earth rotates, the wind blows west (clockwise) of the equator and east (counterclockwise) south of the equator.

Then, what does cause these rivers of water we call currents? The three factors that are most important in causing water movement are:

1. differences in density of the waters
2. the earth's rotation
3. wind.

Ideally the combined factors would produce currents like those shown below.

OCEAN CURRENTS


Labrador Current
North America
California Current
Japan Current
North Equatorial Current
South Equatorial Current
South America
Australia
Peru Current

The differences between our ideal currents and the real currents seen on our earlier map are in part due to the shape of the earth's land masses.

How do these currents influence living things? Our gray whale could give us one answer. Currents can help or hinder the movement of animals. Because they move water of different temperatures, currents also have an influence on where plants and animals can live. Currents help determine the course of ships. Ships save fuel and time by traveling with currents. In days past, currents affected where people could travel by sea. . Because of this fact, currents affected the migration and settling of people. Finally, the speed and temperature of currents can affect the climate of the land near which they pass.

7. What are three factors important in causing currents?

   a.

   b.

   c.

8. What are three ways in which currents affect living things?

   a.

   b.

   c.

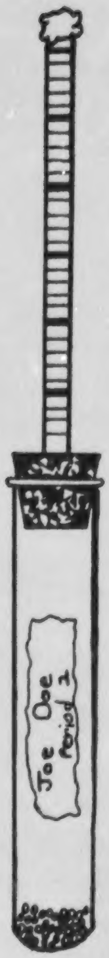
For an interesting view of how currents may have affected the migration and settling of people, read Kon-Tiki by Thor Heyerdahl.

In the following activities you will have an opportunity to examine some of the factors that cause ocean current.

THE HYDROMETER

Before you can look at some of the factors that cause ocean currents you need to have the proper tools.

You may be familiar with such standard measuring devices as the thermometer, balance, and graduated cylinder. In this activity you will make a commonly used special measuring device called a hydrometer. It is used to measure very small difference in the density (or heaviness) of water. As you have seen, not all sea water has the same density. These density differences are very important.



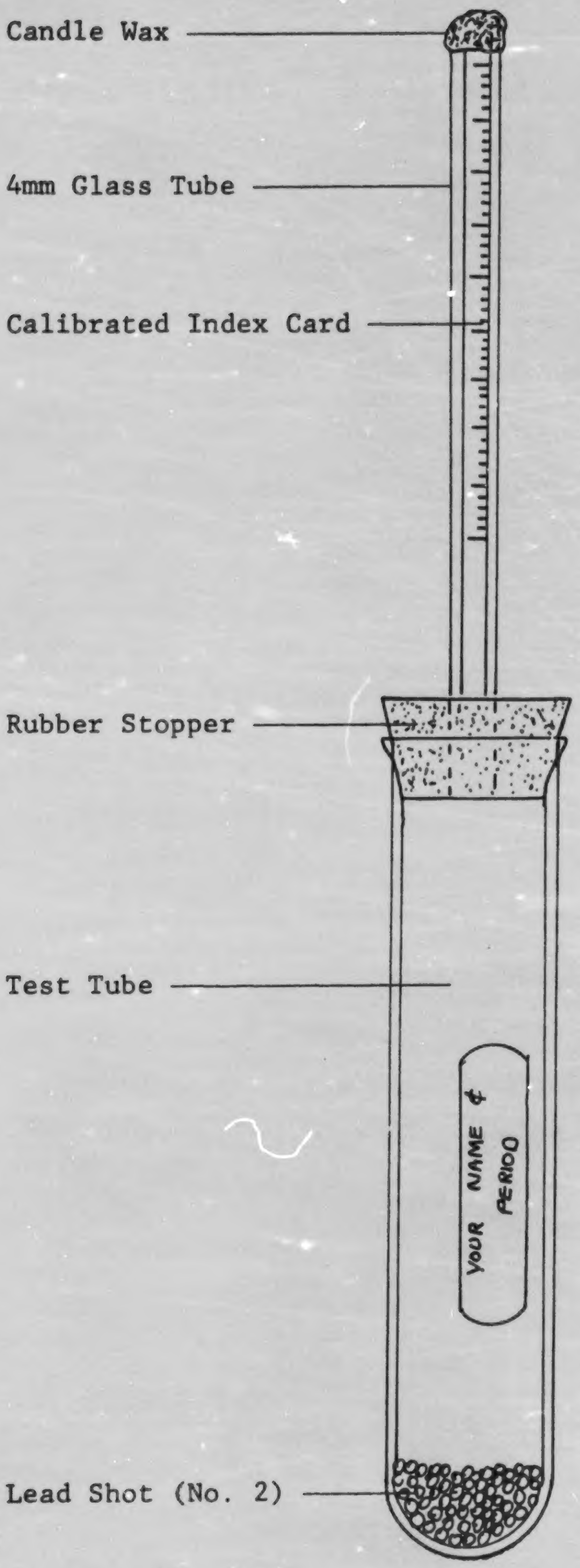
HYDROMETER

Materials:

12 x 75 to 15 x 150mm test tubes
one hole stopper to fit
50 No. 2 lead shot
4mm ID glass tubing X about 120mm
wax candles
matches
100ml graduated cylinders
"standard water"
unknown solution A,B,C
index card
scissors
paper
pencil

Procedure:

1. Obtain an index card. Use a pencil to mark the edge of a notecard every 1/16 inch (pardon the use of a four letter word but in this case it is exactly what is needed). Make every 5th mark extra heavy. (twice as wide a line)
2. Obtain a piece of glass tubing and scissors Use scissors to trim off the marked edge of the card. Slip the strip of card into the glass tube.
3. Obtain a wax candle and matches. Light the candle. Completely seal off one end of the tube by dipping it in candle wax. Next trim off any paper sticking out of the glass tube.
4. Insert the unwaxed end of the glass tube in a rubber stopper. If you wet the outside of glass tube it will go into the stopper more easily.
5. Write the names of everyone in your group on a small piece of paper with a pencil. Put the paper in your test tube with names showing.
6. Obtain about 50 lead shots. Put the lead shots in the test tube and then put in the stopper. Your hydrometer should look something like the one on the next page.


Candle Wax
4mm Glass Tube
Calibrated Index Card
Rubber Stopper
Test Tube
YOUR NAME & PERIOD
Lead Shot (No. 2)

HYDROMETER

7. Obtain a 100ml graduated cylinder. Fill your graduated cylinder with 85ml of "standard water" which has a density of 1.000 g/ml.

8. Carefully lower your hydrometer into the graduated cylinder. If it sinks and stays on the bottom, take out some of the lead shots. If it floats with most of the scale out of the water, add more lead shots. Keep doing this until the water comes as close to the second dark line from the top as possible.

9. A final adjustment is made by tightening or loosening the stopper a tiny amount. Keep adjusting your hydrometer until the water line is right at the second dark line.

10. Once the hydrometer has been adjusted do not move the tube or the stopper or it will be necessary to go back and adjust it again.

11. The second dark line shows a density of 1.000 g/ml. Each line below that line represents increase in density of 0.001 g/ml.

12. Discard the "standard water". DO NOT return the standard solution to the original container. Pour it down the sink.

13. In your graduated cylinder obtain 85ml of solution A. Use your hydrometer to find the density of solution A.

    Record the density of solution A:____________

    (Hint: remember each line below the second dark line equals a density increase of .001 g/ml. Simply count the lines, multiply by .001 g.ml and add to 1.000 to find the density of A)

14. Repeat step 13 for solutions B and C. Record the densities of solutions B and C in the space below:

    Density of solution B: ______________________

    Density of solution C: ______________________

Analysis and Interpretation:

1. Adding salt to water increases the water's density. Which solution has the greatest amount of salt in the water?

2. The density of sea water is 1.025 g/ml. Which solution is most likely sea water?

3. If your hydrometer is properly calibrated and sinks to the top line, what is the density of the solution?

4. What is the density of solutions which sink to each of the marks?

A. ______

B. ______

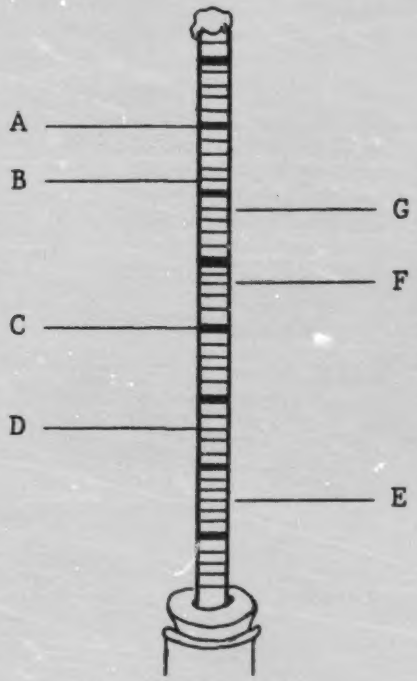
C. ______

D. ______

E. ______

F. ______

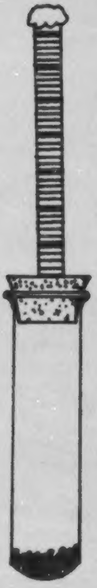
G. ______



5. Where in the oceans would you expect to find the water with the greatest density?

6. a. What would be the approximate density of melting polar ice? (Hint: read the paragraph following question 4 in the reading entitled "November 1").

   b. What would be the approximate density of sea water near ice that is beginning to form?



HEATING IT UP

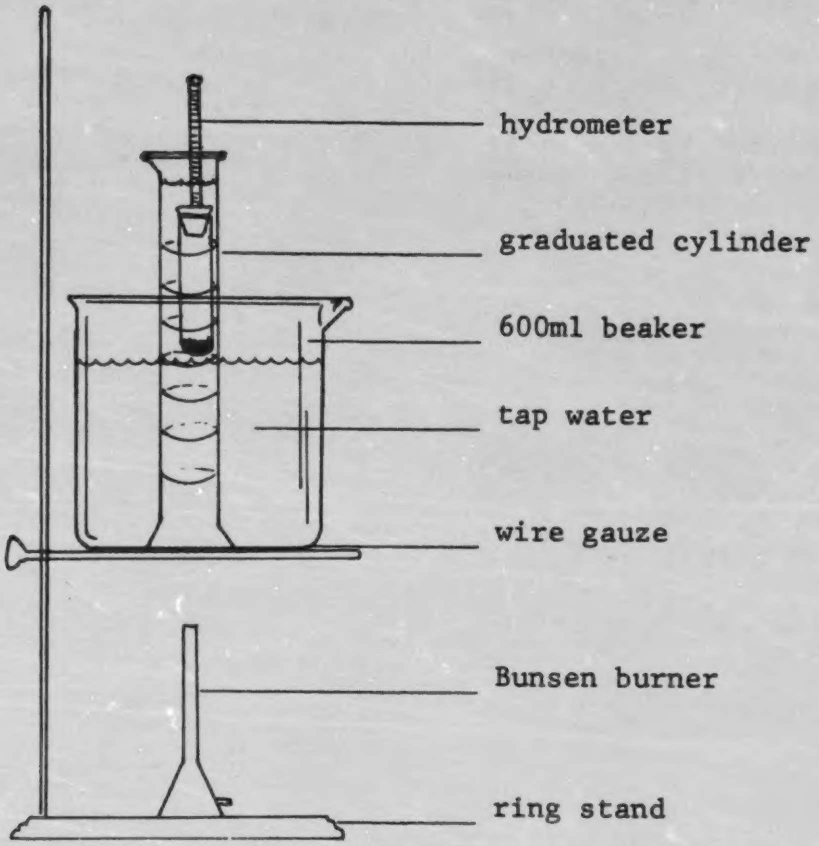
Most visitors to Hawaii spend at least some time swimming in the ocean waters. Very few visitors to Alaska go swimming in the ocean. Do only non-swimmers vacation in Alaska or is there some other reason few people swim in the Bering Sea or Gulf of Alaska? Did I hear you say the water is warmer in Hawaii? Exactly right. The temperature of the ocean is not the same everywhere. In general, the farther north or south you move from the equator, the cooler the ocean water tends to be. Water temperature also changes with depth. The deeper you dive, the colder the water tends to be. In the activity which follows you will have an opportunity to observe how these changes in temperature affect ocean waters.

Materials:

hand-built hydrometer
100ml graduated cylinder
"standard water"
sea water
600 ml Griffin beaker
tap water
ring stand
iron ring
bunsen burner or alcohol lamp
wire gauze
thermometer (-20°C to 110°C)
watch or timer with second hand
graph paper

Procedure:

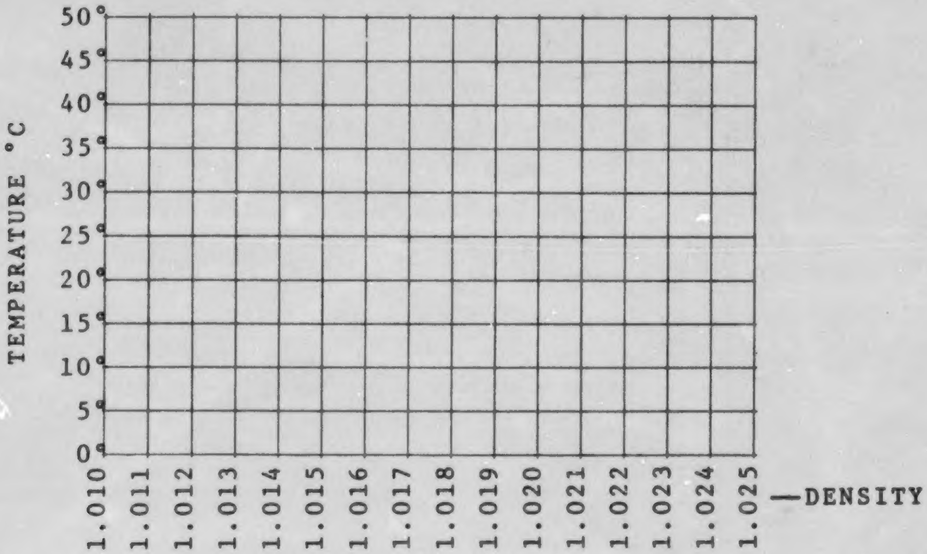
1. Check your hydrometer in standard solution to see if it is still properly adjusted. If the water line is no longer at the second dark line, readjust your hydrometer. You may make small adjustments by tightening or loosening the stopper a tiny amount.
2. Obtain a 100ml graduated cylinder. To your graduated cylinder add 85ml of sea water.
3. Obtain a 600ml beaker and fill it 2/3 full of cold tap water. This will become a water bath.
4. Obtain a ring stand, iron ring and wire gauze. Place the iron ring on the ring stand. Leave enough space beneath the ring for a Bunsen burner or alcohol lamp. Put the wire gauze on the iron ring.
5. Place the Bunsen burner or alcohol lamp under the wire gauze. Place the beaker of tap water on the wire gauze.
6. Stand (DO NOT POUR) the graduated cylinder of sea water in the beaker of water (water bath).
7. Obtain a thermometer. Put your hydrometer in the sea water and hold the thermometer in the water bath (the thermometer should be held so it does not touch the glass). Your set-up should look something like this:


hydrometer
graduated cylinder
600ml beaker
tap water
wire gauze
Bunsen burner
ring stand

8. On your data chart record the beginning temperature of the water bath and the density of the sea water.
9. Obtain a timer or watch with a second hand. Light the Bunsen burner or alcohol lamp. On your data chart record the temperature of the water bath and the density of the sea water every ½ minute while you gently heat the water.
10. Keep taking readings until the temperature of the water bath reaches 50°C.
11. Lift the graduated cylinder up every few seconds to keep the bottom from getting too hot.

Analysis and Interpretation:

1. Obtain a piece of graph paper. Make a vertical line (axis) and a horizontal line (axis) near the lower right corner. Label the horizontal axis "density". Label the vertical axis "temperature". Divide each axis into convenient units. Your paper should look something like this:



Plot your data on your graph paper and connect the points with a smooth line.

2. What happens to the density of sea water as it is warmed? Cooled?

3. Where would you expect to find the warmest sea water? Coolest sea water?

4. If all you had to consider was the temperature of the water, where would you expect to find the least dense sea water: The most dense sea water?

5. Use the graph to estimate the density of sea water at:

   a. 25°C

   b. 35°C

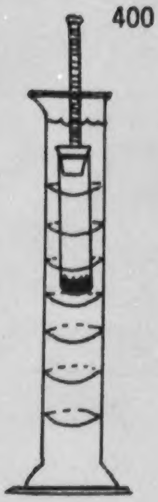
   c. 45°C

6. Fully loaded ships from Indonesia (tropical climate) often float higher in the water as they travel northward toward Washington. Explain why.

DATA CHART

Time (minutes)	Temperature	Density
0		
½		
1		
1½		
2		
2½		
3		
3½		
4		
4½		
5		
5½		
6		
6½		
7		
7½		
8		
8½		
9		
9½		
10		

(stop at 50°C)



OL' SEA SALT

We have seen that the temperature of ocean water differs in different parts of the ocean. The amount of salt dissolved in sea water also differs in different parts of the ocean. In places where there is little flow and a high rate of evaporation, the amount of salt in the water is high. In places where large rivers flow into the ocean, the amount of salt in the water is low. The amount of salt in the water is called salinity. Salinity affects the density of water. Just as differences in density due to temperature cause currents, differences in density due to salinity cause currents. Ocean currents are caused by a combination of differences in density due to temperature and salinity and to other factors. In the following activity you will investigate the effect of salinity on density.

Materials:

hand built hydrometer
100ml graduated cylinder
"standard water"
4% salt solution
150ml Griffin beaker

Procedure:

1. Check your hydrometer in standard water to see if it is still properly adjusted. If the water line is no longer at the second dark line, readjust your hydrometer.

You may make small adjustments by tightening or loosening the stopper a tiny amount.

2. In a 100ml graduated cylinder, obtain 85ml of 4% salt solution. Measure the density of the 4% solution. Record the density in your data table.
3. Obtain a 150ml Griffin beaker. Make a 2% solution by pouring 50ml of the 5% solution into the beaker. Add 50ml of standard water to the beaker and find the density of the resulting 2% solution. Record the density in your data table.
4. Repeat the process with the 2% solution by mixing 50ml of 2% solution and 50ml of standard water. Find the density of the new 1% solution. Record the density in your data table.

Analysis and Interpretation:

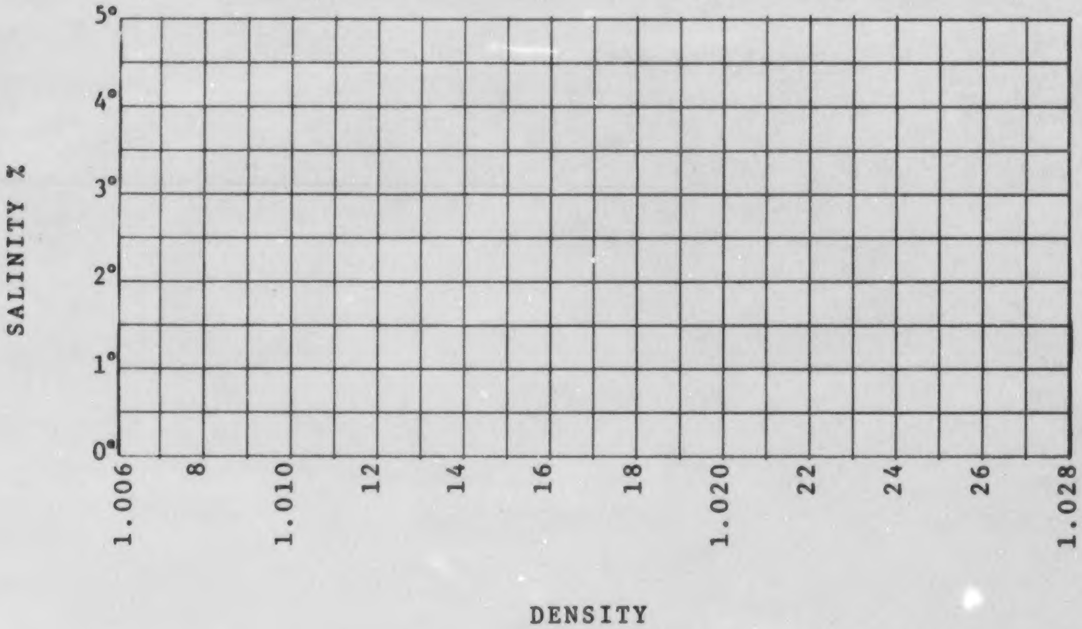
1.

DATA TABLE

Solution	Density
4%	
2%	
1%	

2. Obtain a piece of graph paper. Make a vertical line (axis) and a horizontal line (axis) near the lower right corner. Label the horizontal axis "density". Label the vertical axis "percent solution".

Divide each axis into convenient units. Your paper should look something like this:



Plot your data or your graph paper and connect the points with a smooth line.

3. If 50ml of 1% solution were mixed with 50ml of water what percent solution would be made? Use your graph to predict the density of such solution.

4. Use your graph to find the density of a 3% solution.

5. Sea water has an average density of 1.025 g/ml. Use your graph to estimate what its average salinity would be.

6. What do you predict river water will do if it flows into the ocean and does not immediately mix with the sea water? (This is common for some large rivers).

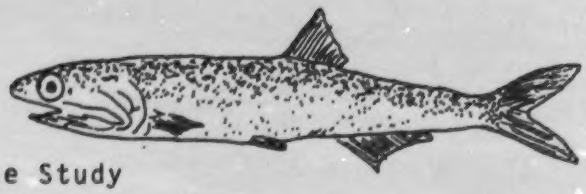
7. From what you found out in this lab, explain why deep ocean water is saltier than surface water?

8. Where in the oceans would you expect to find:

   a. the waters with the lowest salinity.

   b. the waters with the highest salinity.

9. What do we call the movement of dense ocean waters to areas of less dense water?



CURRENTS: A Case Study

El Niño. They call it "The Child", because it traditionally begins around Christmas time.

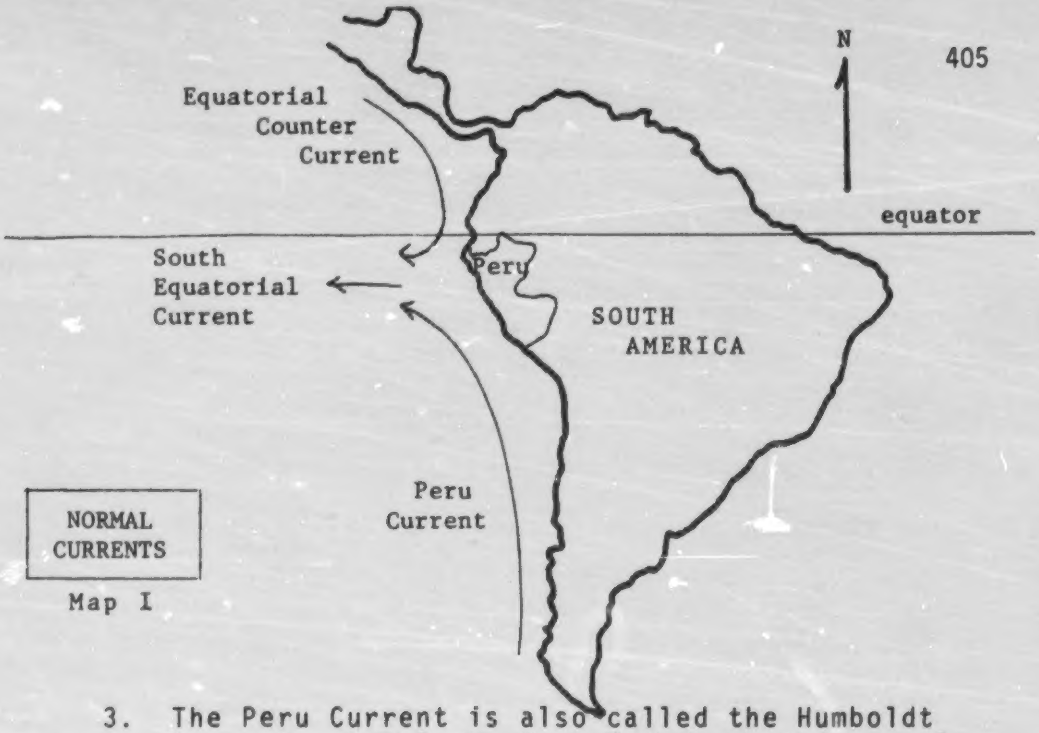
But El Niño brings no joy. When it comes, millions of small fish called anchovy disappear. Other fishes, birds, and marine mammals die. The economy of Peru suffers a severe setback.

El Niño is a weather-related change in ocean currents. Its last appearance saw Peru's annual anchovy catch drop from over 10 million metric tons per year to less than 2 million metric tons per year. How can currents play such a major role in economic disaster?

1. What is El Niño?

2. What effect does El Niño have on anchovy catches?

In normal years, the west coast of South America is washed by the cold Peru Current which collides with the weak Equatorial Counter Current near the equator. The Equatorial Counter Current is easily pushed aside and with the Peru Current forms the South Equatorial Current. The map below shows the location of normal year currents.


N
equator
Equatorial Counter Current
South Equatorial Current
Peru
SOUTH AMERICA
Peru Current
NORMAL CURRENTS
Map I

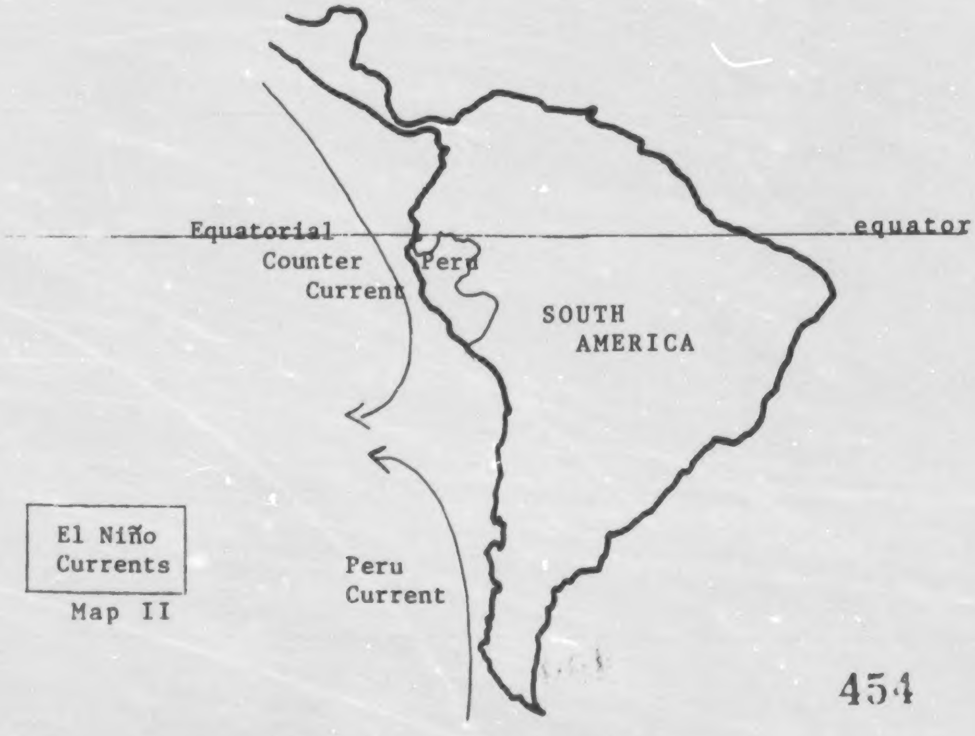
3. The Peru Current is also called the Humboldt Current. Label the Humboldt Current in map 1.

The water in these two currents is very different. The water of the Equatorial Counter Current has traveled twice across the wide Pacific Ocean. The water has been stripped of nutrients and is very warm. In contrast the water of the Peru Current is the result of cold Anarctic waters and upwelling waters from along the coast of South America. This water is rich in nutrients, and so cold that Antarctic birds are found living in it as far north as the equator.

Three of the major industries in Peru are directly or indirectly dependent upon the Peru Current. Although Peru is a small nation, it presently ranks third among all nations of the world in annual fish catch. The fish, which are abundant in the cold coastal waters, bring millions of sea birds which nest along the coast.

Tons of resulting guano is processed and sold as fertilizer throughout the world. The fertilizer industry is the second major industry dependent upon the Peru Current. Finally, tourists are drawn to resorts along the Peruvian shores. The tourists provide the third major industry.

Now, once in every eleven years or so something happens to change global wind patterns in the Southern Hemisphere. Some scientists think this change may be related to the cycle of sunspots, but no conclusive link has yet been demonstrated. Whatever the reason, the weakened wind patterns have a disastrous influence on the normal movements of water in the oceans. The weakened winds cause a general weakening of the Peru Current. The weakened current is no longer able to push aside the Equatorial Counter Current which suddenly invades coastal areas of Peru, which are normally washed by the Peru Current (See Map II). El Niño has arrived.



El Niño
Currents

Map II

When El Niño visits, the upwelling of coastal waters which brings colder, nutrient-rich deep water to the surface stops. Surface waters become warmer and salinity decreases. The results can be disastrous for marine and bird life as well as for the Peruvian fishing industry. Microscopic plants quickly use up all of the nutrients in the water. The anchovy disperse (swim in different directions). The millions of sea birds that feed on the anchovies disperse or die.

4. What is one factor which helps cause the decrease in water density seen when El Nino arrives?

Other fishes and marine mammals also die. Rotting fish, mammal and bird carcasses can cover local beaches. Hydrogen sulfide gas released by the break-down of the dead animals and plants blackens the hulls of ships and boats in the area. The phenomenon is called the "Callao Painter" because it often occurs off the Peruvian Port of Callao.

5. What causes the "Callao Painter"?

Consider the econmic impact this change has on industries in Peru. The fish follow the cold water hundreds of miles from the coast. The fish catch drops. The sea birds follow the fish, so fertilizer production stops. Warm-invading waters kill existing plants and animals. The stench of the dead organisms discourages the normal tourist trade. The economy of Peru collapses.

6. What are the three major Peruvian industries that are affected by El Niño?

   a.

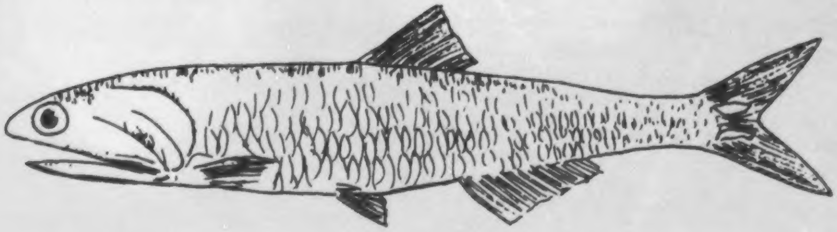
   b.

   c.

The story doesn't end here. Peru is the world's leading producer of fishmeal. The fishmeal is used in chicken and livestock feed. El Niño causes a drastic drop in fishmeal production. The price of chicken feed skyrockets. The price of chickens in your market also skyrockets. Thus, changed ocean conditions off Peru result in higher costs for food to the consumer.

7. How does El Niño result in higher chicken prices?

"El Niño" current usually lasts only 8 to 12 months, but in that period of time it puts pressure on the world supply of protein and thereby drives up the price of everything from salmon to soy beans. How well you eat and how well we relate to our South American neighbors does depend on the flow of the Peru Current.



ANCHOVETA

MINING THE OCEAN FLOOR

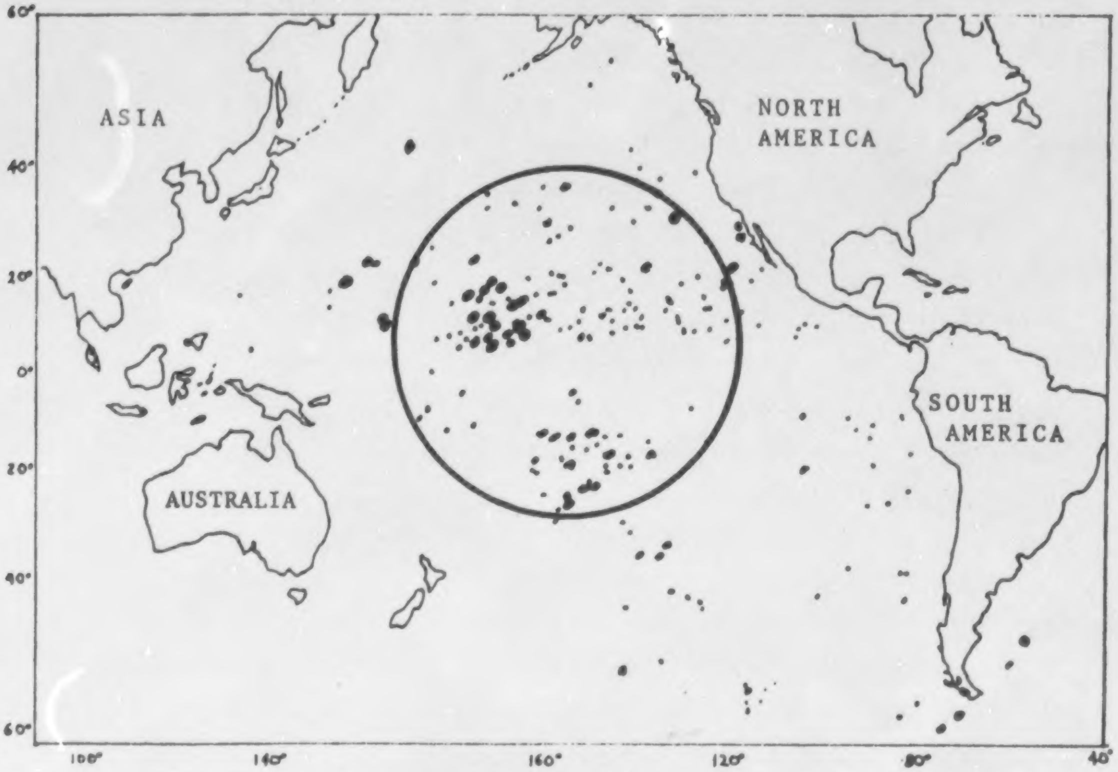
TEACHER BACKGROUND - November 21 and Getting The Word Across

"November 21" provides a glimpse at the expanding field of deep ocean mining. For the last decade, industrial nations have been poised on the edge of the sea awaiting completion of an international treaty to govern deep sea bed mining. During the waiting period, many of the technological problems inherent in deep-sea mining have been resolved. Field testing of deep-sea mining systems has given the National Oceanic and Atmospheric Adminstration an opportunity to answer some of the environmental concerns. Many serious questions, however, remain to be resolved. As the value of the deep sea minerals increases, the pressure to mine without a treaty and also without knowledge of potential environmental damage increases. The issues are complex, the potential rewards great. An excellent overview of this one thousand billion dollar game of international intrigue was produced for Public Television by the NOVA series. The documentary, entitled "Cashing In On The Ocean" is available from Time-Life Films in 16mm and video-tape formats. The complete transcript of the show is also available from NOVA, WGBH Boston (125 Western Avenue; Boston, Massachusetts 02134) for $2.00.

Duplicate the text and activity pages. One set is recommended per student. These exercises may be completed by individual students as in-class or homework assignments. "Getting the Word Across" is a vocabulary reinforcing activity utilizing some of the unknown vocabulary from "November 21". Upon completion plan to allot time for a class discussion of these materials. During your discussion emphasize the complexities of the deep-sea mining issue from both a social and ecological perspective.

KEY

1. a. The area of greatest interest to prospective miners is that in which the nodule concentration is the greatest. That area is circled on the map below.



b. While the reasons for the choice will vary, most students will base their choice on consideration related to the density of nodules.

2. The approximate value of the manganese nodules in the test area is $50 trillion (50,000,000,000,000).

$$(\text{i.e. } \frac{10 \times 10^6 \text{ dollars}}{\text{square mile}} \times 5{,}000{,}000 \text{ mi}^2)$$

What does this figure mean? You might have your students calculate the number of fancy cars, houses, etc. For example, you could buy 1,000,000,000 cars at $50,000 each. An ultra fancy car for one out of every four people on the face of the earth.

The average cobalt content will likely be less than 1%. We are none-the-less talking about a giant sum of money.

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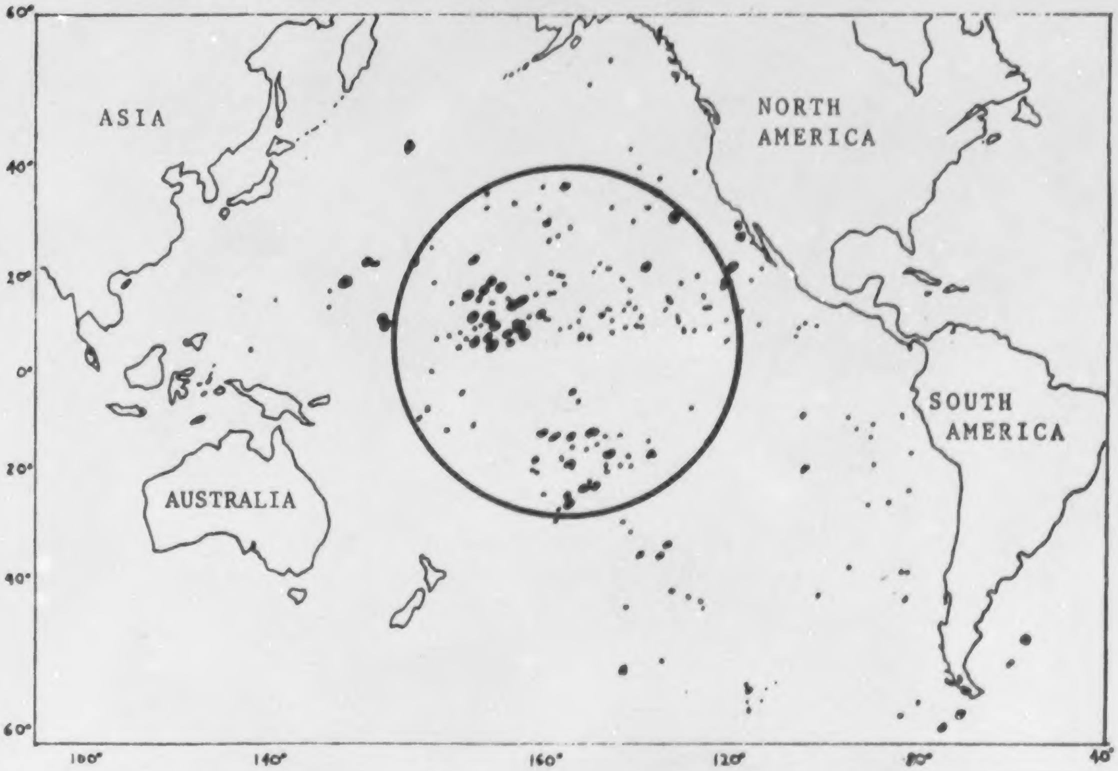

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The average cobalt content will likely be less than 1%. We are none-the-less talking about a giant sum of money.

3. A non-renewable resource is a useful item which once used is no longer available to mankind. Non-renewable resources include fossil fuels, metals, and similar finite items. Renewable resources, for example timber, can be regenerated by nature with man's help. The definition of non-renewable resource must come from context clues.

4. Your students will be able to suggest a variety of problems that may be caused by deep-ocean mining systems. Perhaps the most obvious problem lies in the fact that any animals or plants living on the bottom are sucked up by the collector. Other problems (reduced light for photosynthesis, increased damage from fine particles, etc.) may be anticipated at the surface as well as on the bottom. This question is designed to start your students thinking about the possible effects of such deep ocean mining systems.

5. a. In a one hour period the Cobalt Blue will mine 208.33 tons in one hour.

   (ie. $\frac{5{,}000 \text{ tons}}{\text{day}} \times \frac{1 \text{ day}}{24 \text{ hours}} = 208.33$ tons/hour)

   b. In a year of 300 work days the Cobalt Blue will recover 1,500,000 metric tons of nodules.

   (ie. $\frac{5{,}000 \text{ tons}}{\text{day}} \times \frac{300 \text{ days}}{\text{year}} = 1{,}500{,}000$ tons/year)

6. a. In a 300 day work year, 66,600 acres will be skimmed by the Cobalt Blue.

   (ie. $\frac{222 \text{ acres}}{\text{day}} \times \frac{300 \text{ days}}{\text{year}} = 66{,}600$ acres/year)

   b. In a year of 300 work days, 15,000 acres will be compacted by the treads.

   (ie. $\frac{50 \text{ acres}}{\text{day}} \times \frac{300 \text{ days}}{\text{year}} = 15{,}000$ acres/year)

   c. The total number of acres skimmed and compacted by the Cobalt Blue each year is 81,600.

   (ie. 66,600 acres skimmed + 15,000 acres compacted = 81,600 acres)

7. a. In a 300 day work year, 10,800,000 tons of sediment would be sucked up by the mining system.

   (ie. $\frac{36{,}000 \text{ tons}}{\text{day}} \times \frac{300 \text{ days}}{\text{year}} = 10{,}800{,}000$ tons/year)

   b. In a 300 day work year, 518,100 pounds of living plants and animals would be sucked up by the mining system.

   (ie. $\frac{1{,}727 \text{ pounds}}{\text{day}} \times \frac{300 \text{ days}}{\text{year}} = 518{,}100$ pounds/year)

8. In a 300 day work year, 300,000 tons of sediments are released at the surface.

   (ie. $\frac{1{,}000 \text{ tons}}{\text{day}} \times \frac{300 \text{ days}}{\text{year}} = 300{,}000$ tons/year)

   By now the purpose of these mathematical manipulations should be obvious: to impress upon your students the enormity of the project contemplated.

9. Your students may have a variety of thoughts regarding what will happen to the sediment. The majority of the sediment will eventually sink: what happens to it before it sinks and what happens to the organisms and objects upon which it settles are the questions being studied by oceanographers.

10. The increased sediments affect plant growth by reducing the light available for photosynthesis.

11. Your students may have a variety of suggestions regarding how fish respond to the sediment discharge. Evidence seems to indicate that most fish will leave the area. (In this respect, fish have an advantage over many bottom dwellers). If commercially valuable fish species (like tuna, bill fish, etc.) leave the area mining may have an adverse effect upon the fishing industry.

12. If microscopic animals do indeed cause manganese nodules, the most obvious effect of mining which destroys the animals living on the bottom may be that no new nodules will be formed.

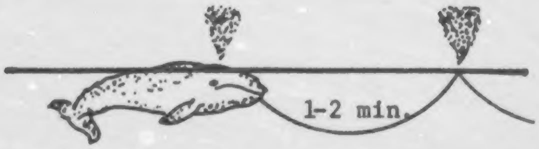
13. The statement that disturbances on the bottom will have little effect on the surface fails to view the ocean as an integrated whole. The fact that a one month study shows no effect on the surface cannot be construed to indicate that a multi-year mining program will similarly have no effect. In short, the statement appears, to this author, to be an unreasonable conclusion. Your students may have a variety of opinions. You should note that this question does, in fact, ask for an opinion. As such, there are no right or wrong answers. In your discussion of this question review the dangers in making a long term prediction from highly limited data.

KEY - Getting The Word Across

1. NODULES
2. COLLECTOR
3. EFFLUENT
4. PLUME
5. EGGSIZE
6. SEDIMENT
7. MANGANESE
8. LIGHT
9. PLANKTON
10. FILTERING
11. NONRENEWABLE

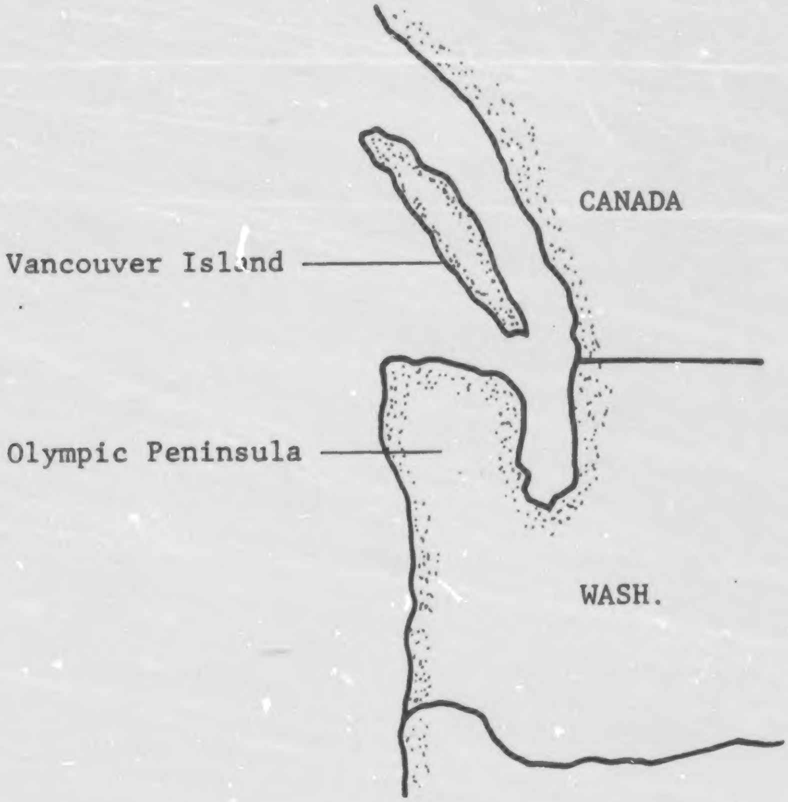
KEY WORDS

benthic plume
cobalt
compact
conclusion
copper
crystal
deep ocean mining system
discharge
disturbance
dredgehead
ecological
effluent
environment
estimated
filtering
formation
iron
manganese nodule
nickel
nodule
non-renewable resource
organism
origin
penetration
phytoplankton
recover
renewable resource
sediments



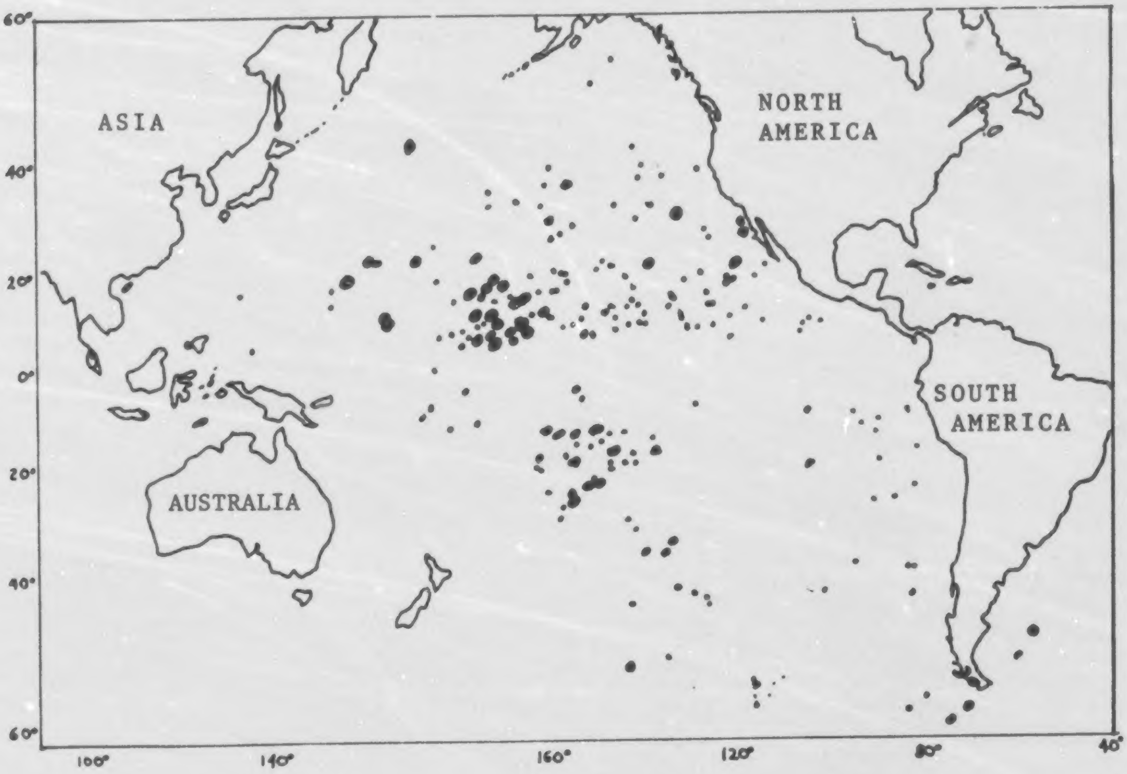
NOVEMBER 21

Swimming, breathing, swimming, breathing, the gray whales move steadily southward. Our gray whale has left behind the snow and sleet. In their place come the rains which give life to the forests, ferns, and mosses of Vancouver Island and the Olympic Peninsula.



The days are longer than in the Arctic. The sea around our gray whale comes alive with sounds and images. Land shapes with sparkling lights are near at hand. In the two months since she left the Arctic, she has traveled nearly 4000 miles.

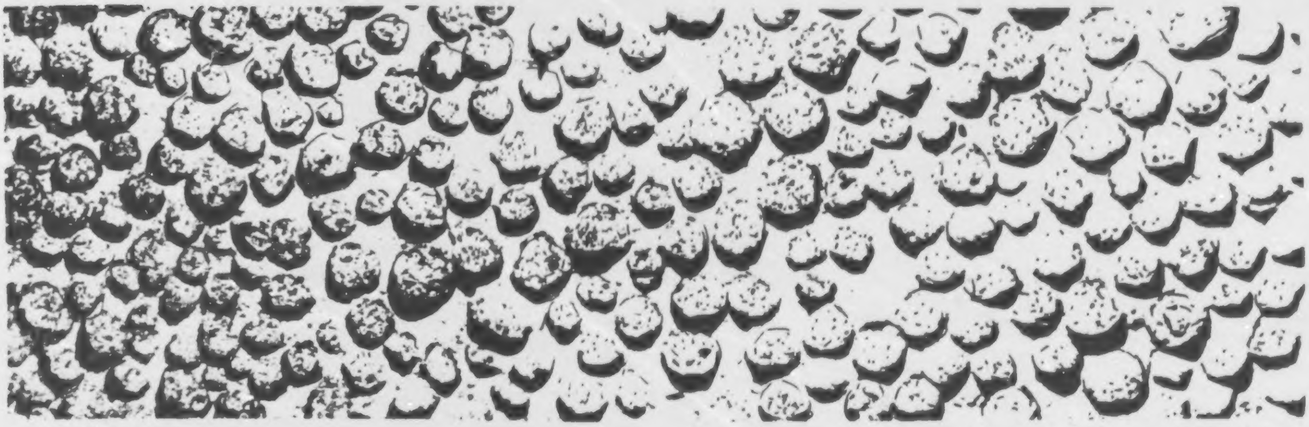
Her swimming now takes her into an area in which the sea-bottom has a great interest for mankind. She has entered the home of the manganese nodule, special "rocks" rich in iron and manganese.


ASIA
NORTH AMERICA
SOUTH AMERICA
AUSTRALIA
60°
40°
20°
0°
20°
40°
60°
100°
140°
160°
120°
80°
40°

1. a. As President of SEA-MINE Inc., you wish to mine manganese nodules. On the map above circle the area in which you would begin mining.

   b. Why did you choose the area you circled?

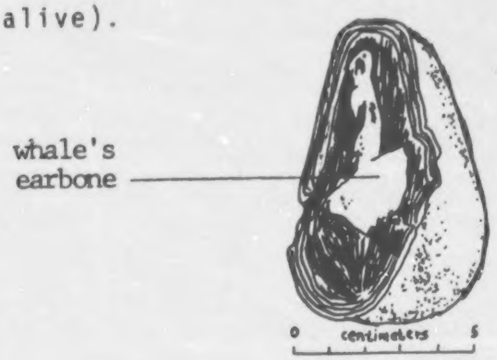
What are these "rocks"? They were first brought up from the Pacific ocean floor by the British research vessel HMS Challenger one hundred years ago. These potato-shaped "rocks" are not pretty. Some are small enough to fit under a fingernail. Most of those seen with underwater cameras are eggsize and larger. They lie in a single layer on the ocean floor. In some places they are widely scattered. All together manganese nodules are estimated to cover 25% of the sea floor.



The nodules differ in their make-up from area to area. They are largely iron and manganese with small amounts of copper, nickel, and cobalt. The small amounts of copper, nickel and cobalt are what interest mining companies. These metals are important to industry. They are also valuable. For example, if the nodules contain only one percent cobalt their value runs to over $10 million per square mile.

2. The three deep mining test sites currently being explored cover about 5 million square miles of ocean floor. If the average cobalt content is 1%, what is the approximate value of the manganese nodules in the test area?

What is the origin of these valuable lumps? Scientists are not sure but they do have some ideas. A cross-section of a nodule presents an interesting pattern. The nodule is made up of thin layers of varying colors. The cross section looks something like an onion sliced end-to-end. These rings have helped convince scientists that nodules grow. (The growth is more like salt crystal growth than plant or animal growth. The nodules aren't thought to be alive).

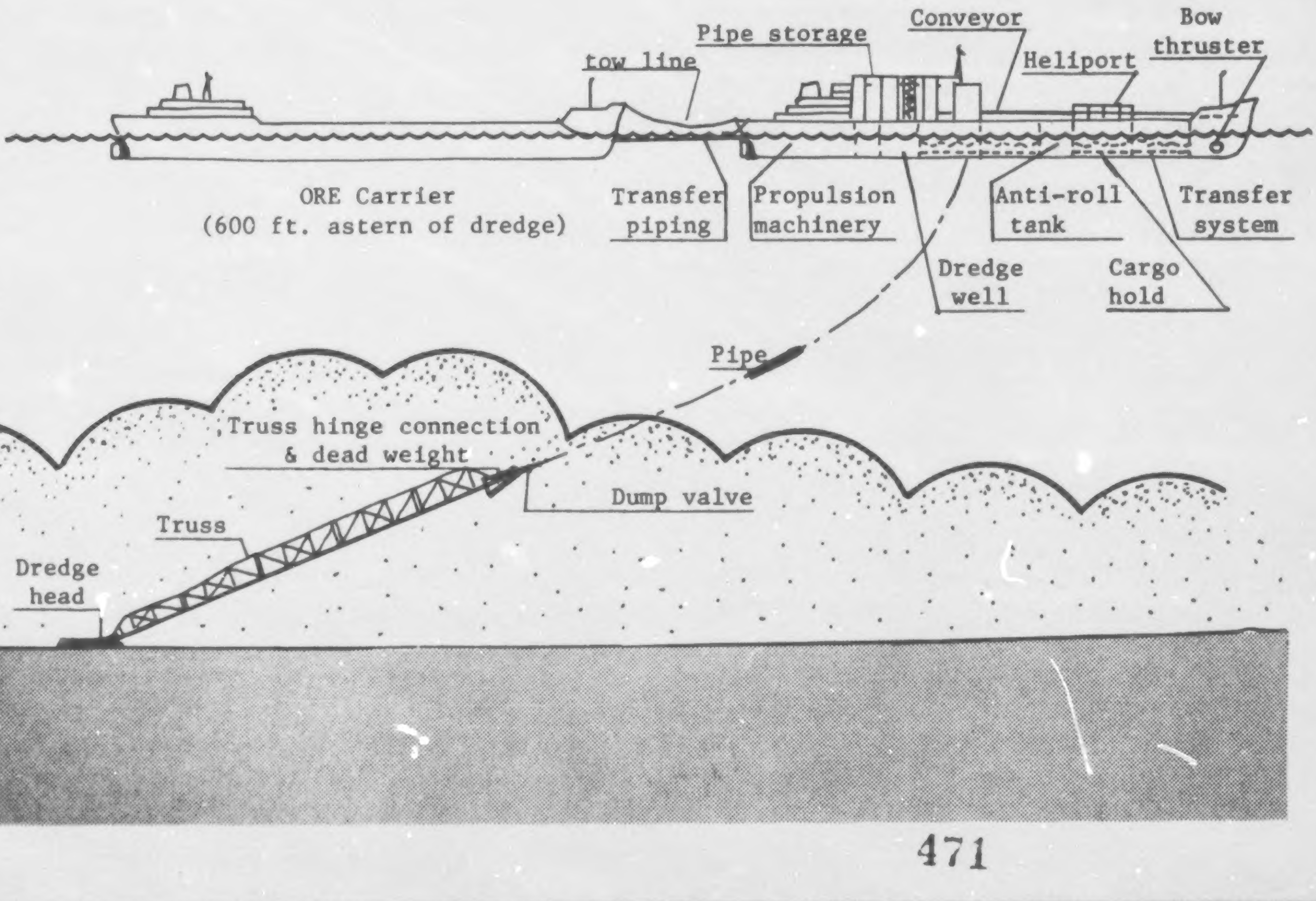


Manganese Nodule

There are more questions about nodules than there are answers. Nodules are older than the sediments on which they sit. How do they remain on top? What keeps them from being buried under new sediments? What determines the chemical composition of nodules? What is the role of animals in nodule formation? Some nodules are formed around prehistoric shark teeth. Microscopic organisms add to the growth by building homes on the nodule surface. What is the rate of growth? If the growth rate is as slow as it appears, we must consider the nodules as a "non-renewable" resource, at least for many generations.

3. What is meant by a "non-renewable" resouce?

What does the future hold? The first deep ocean mining system has been tested. The system reaches down through miles of water to scoop up manganese nodules from atop the sediments. Most deep-sea mining systems are similar. A collector, or dredgehead, travels along the sea floor. The collector sucks in nodules, surface sediments, and whatever else lies in its path. The materials are pumped to a ship at the surface. The waste products, or effluent, are discharged at the bottom and at the surface. The bottom discharge is called a benthic plume. The drawing below shows a typical deep ocean mining system.

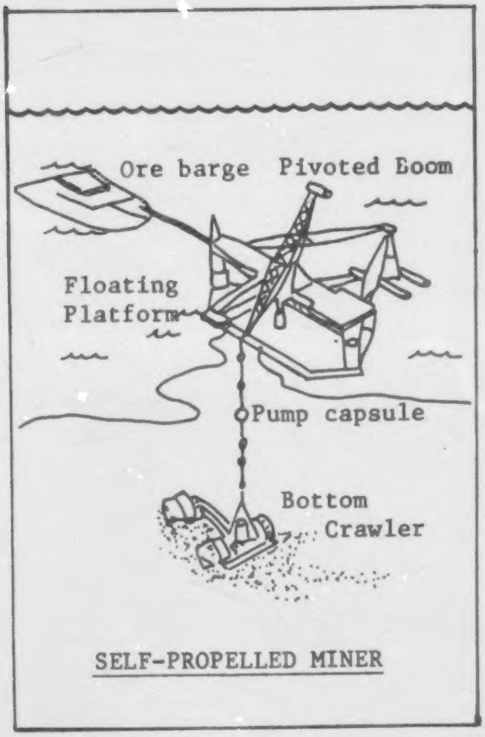

Pipe storage
Conveyor
Bow thruster
tow line
Heliport
ORE Carrier (600 ft. astern of dredge)
Transfer piping
Propulsion machinery
Anti-roll tank
Transfer system
Dredge well
Cargo hold
Pipe
Truss hinge connection & dead weight
Dump valve
Truss
Dredge head

4. What is one possible problem the deep ocean mining system may cause?

Such mining ships will each recover 5,000 to 10,000 metric tons of nodules a day. They will be operating 24 hours a day, about 300 days per year.

5. a. The Cobalt Blue deep ocean mining system can recover 5,000 metric tons of nodules a day. How many tons will it mine in one hour?

   b. How many tons will the Cobalt Blue recover in a year of 300 work days?


Ore barge
Pivoted Boom
Floating Platform
Pump capsule
Bottom Crawler

SELF-PROPELLED MINER

To recover 5,000 tons of nodules, a mining system will have to skim the top from 222 acres of ocean floor. During the process 50 acres of ocean floor will be compacted by the treads of the collector.

6. In a 300 day work year:

    a. How many acres will be skimmed by the Cobalt Blue?

    b. How many acres will be compacted by the treads?

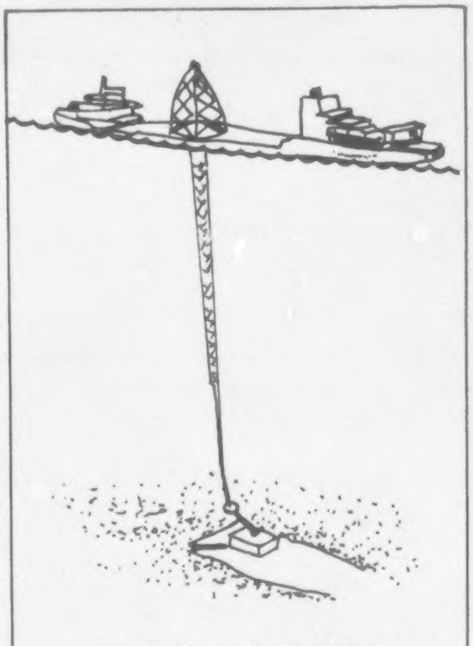
    c. How many acres total will be skimmed and compacted by the Cobalt Blue each year?

With the nodules the mining system would also suck up 36,000 tons of sediment, 1,727 pounds of living plants and 3,530,000 cubic feet of water. Most of this would be spurted back into the lower layer of the sea.

7. In a 300 day work year:

    a. How many tons of sediment would be sucked up by the mining system?

b. How many pounds of living plants and animals would be sucked up by the mining system?



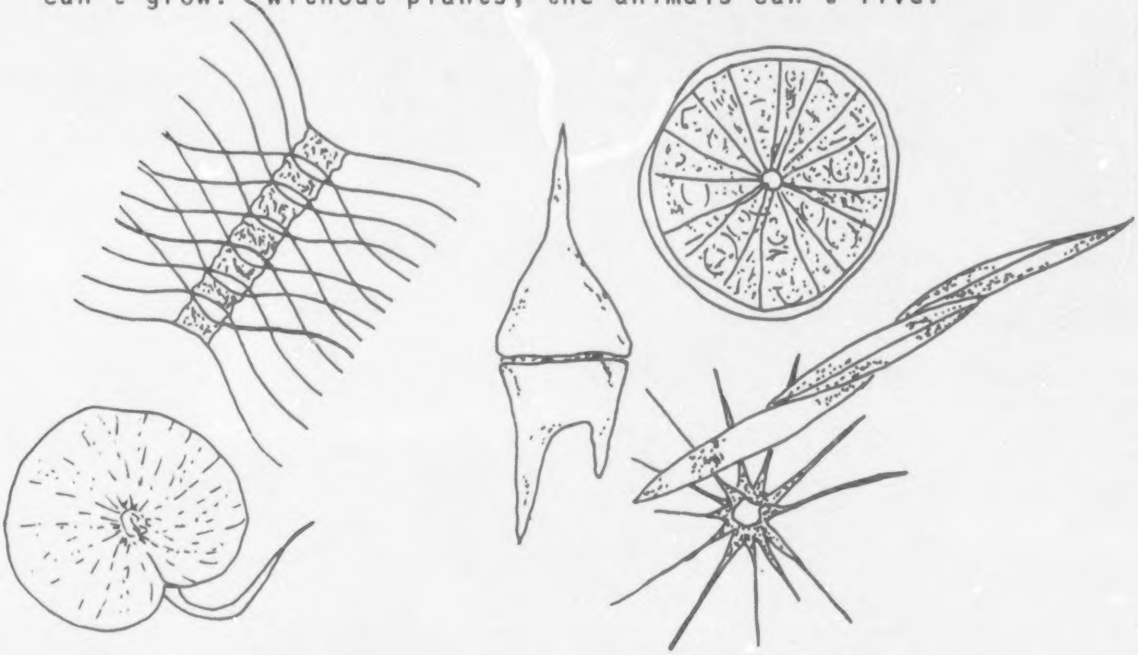
TOWED COLLECTOR MINER

Not all of the effluent is spurted back into the lower layer of the sea. At the surface, 1,000 metric tons of sediment, 50 tons of crushed nodules, 51 pounds of plants and animals, and 706,200 cubic feet of water are released.

8. In a 300 day work year, how many metric tons of sediment are released at the surface?

9. What do you think will happen to the sediment?

It is clear from the amount of materials moved that deep-sea mining will have some important effects on life in the sea. Let's first look at some of the concerns scientists have about the surface effluent. Sediments brought to the surface by mining would greatly reduce light penetration into the upper waters. The microscopic plants, called phytoplankton, which form the basis for all life in the sea need light. Without light the plants can't grow. Without plants, the animals can't live.



Light penetration will increase as soon as the mining system passes. Within 24 hours, the water will clear enough to allow about 50% of the normal growtn. The effect of the sediments will be felt within about 100 kilometers (60 miles) of the miner.

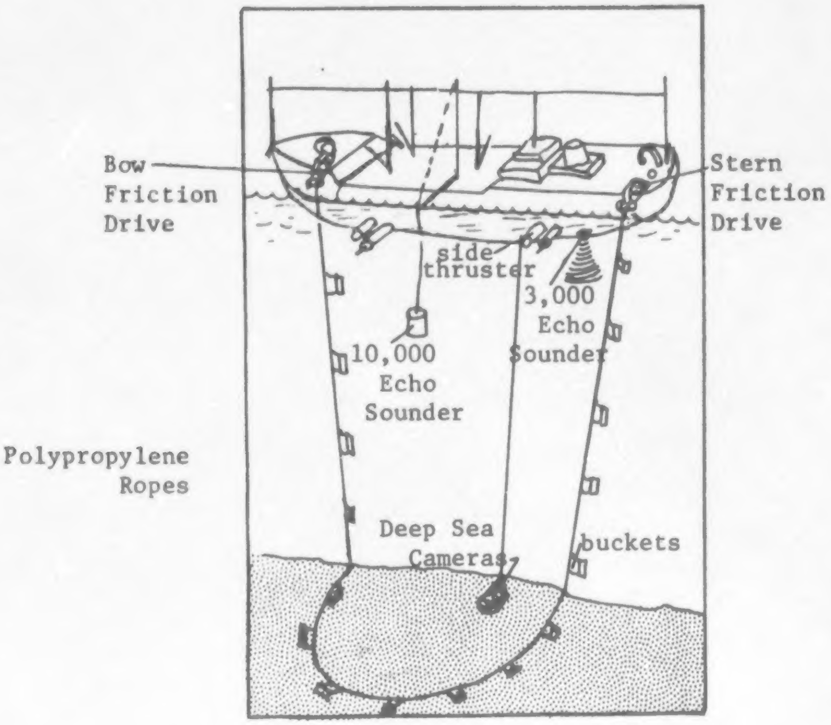
10. How do the increased sediments affect plant growth?

The sediment particles may clog the breathing and feeding parts of marine animals. Microscopic animals which feed by filtering may help the sediment to settle faster.

11. What is one way in which fish may respond to the sediment discharge?

The long term effects of surface sediments on the food chain of the ocean are unknown. What do we know about the bottom sediments? The ocean bottom is a stable environment. Things on the bottom change very slowly. As a result plants and animals on the bottom probably cannot stand sudden changes. The plume of bottom sediments might choke the plants and animals. The 1,727 pounds of plants and animals sucked up each day will definitely be affected. The homes of other animals will be destroyed by the blanket of sediment. Other effects remain to be seen.

12. Some scientists believe that microscopic animals may cause manganese nodules. If this is true, what might be one long term effect of mining which destroys the animals living on the bottom?


Bow
Friction
Drive
Stern
Friction
Drive
side
thruster
3,000
Echo
Sounder
10,000
Echo
Sounder
Polypropylene
Ropes
Deep Sea
Cameras
buckets

Continuous Line Bucket System

Scientists working with deep-sea mining feel it is important to know what ecological upset will be caused by the destruction of bottom animals and plants before large scale mining begins. As one scientist said, "There will be damage to bottom animals and plants; there's no way around that". To reduce the damage, we had better go forth into the sea armed with the knowledge of just what it is that we are doing.

13. One early study of deep-sea mining stated "it appears from study so far that disturbances at the ocean bottom will have little if any effect on the surface." In view of the interrelationships that exist within the sea, do you think this is a reasonable conclusion? Please explain your answer.

GETTING THE WORD ACROSS

Directions: Using the clues at the bottom of the page, complete the spelling of each word.

1. _ _ D _ _ _ _
2. _ _ _ _ E _ _ _ _
3. _ _ _ _ _ E _ _
4. P _ _ _ _
5. _ _ _ S _ _ _
6. _ E _ _ _ _ _ _
7. M _ _ _ A _ _ _ _
8. _ I _ _ _
9. _ _ _ N _ _ _ _
10. _ _ _ _ E _ _ _ _
11. _ _ _ R _ _ _ _ _ _ _ _

1. These special "rocks" are rich in iron and manganese.
2. On the miner, the _________ sucks in the nodules.
3. The waste products discharged from a deep-sea miner.
4. The bottom discharge of wastes is called a benthic_________.
5. On the underwater camera, most of the manganese nodules appear to be ____________.
6. Solid matter which settles out of a liquid.
7. The nodules which deep-sea miners are searching for are made mostly of iron and _____________.
8. Without ________, which sediments reduce, ocean plants can't grow.
9. Microscopic plants living in the ocean are called phyto_______.
10. Microscopic animals that feed by __________ may help the sediment settle faster.
11. If the growth rate is as slow as it appears, nodules are a _____________ resource, at least for many generations.

TEACHER BACKGROUND - To The Bottom

"To The Bottom" provides a "hands-on" sequel to the preceeding discussion on deep-sea mining found in "November 21". In "To The Bottom" your students will have an opportunity to examine the effect of particle size on the rate of sedimentation. The size of the particles discharged at the surface by deep-sea miners will play an important role in determining the effect the discharge will have on marine life, and on where the effect will be felt. Larger particles will settle rapidly. Their effect will be to produce a blanket of suffocating silt on the bottom, an effect which will probably be small in comparison with the effect which the collector-dredge of the deep-sea mining system will have on the bottom.

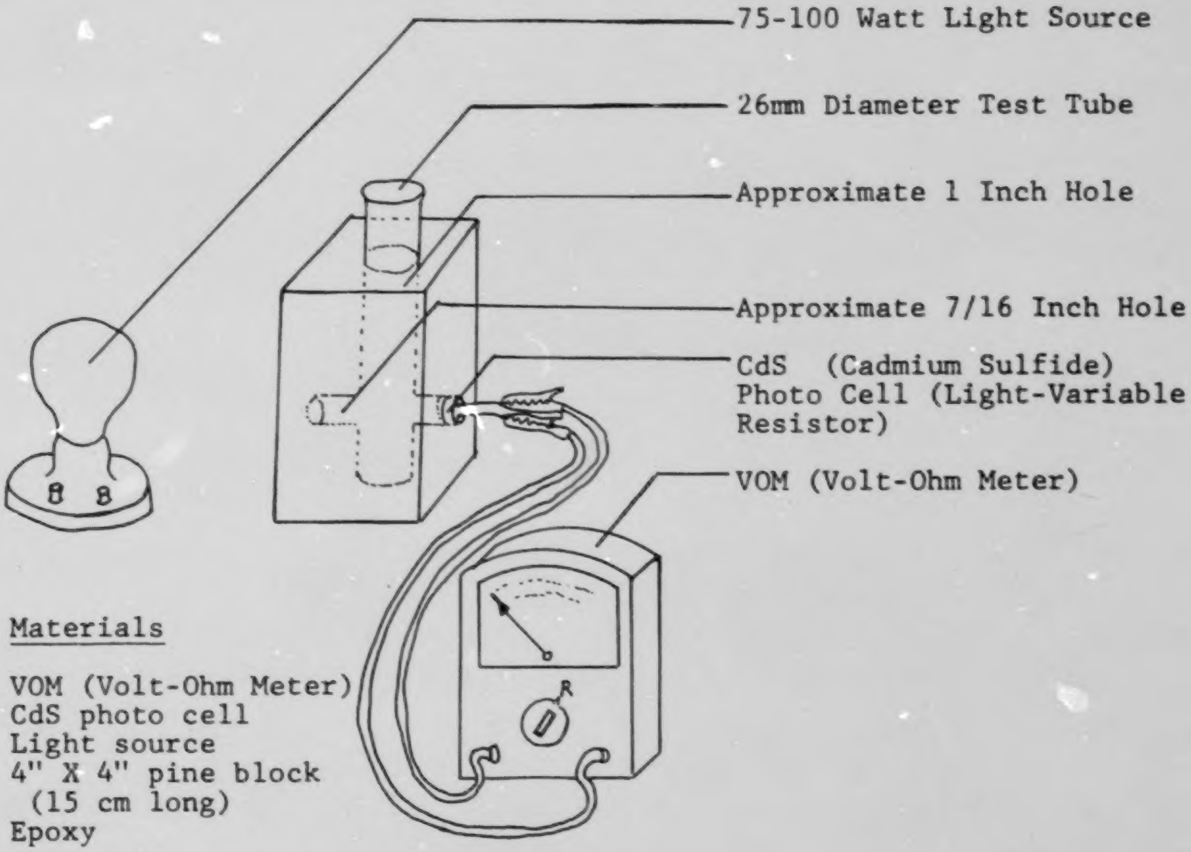
The very fine particles may stay in suspension for quite a period of time. One possible danger is a reduction in light penetration due to the turbidity of the water. Reduced light penetration precipitates a reduction in primary productivity by phytoplankton. This reduction in the base of the food web of the sea may be expected to have at least some local, adverse impact. The fine sediments are also those most likely to clog the breathing and feeding apparatuses of gill breathers and filter feeders. The effect of the fine sediments, then, is more long lived and occurs at or near the lighted, surface zones.

"To The Bottom" requires the use of a photometer. While it may be possible to borrow photometers from an affiliated high school, a reasonably accurate substitute may be constructed at a low cost. The main component consists of an inexpensive VOM (volt-ohm meter) which can be purchased at any electronics supply store for under $10. The other component which you will need to purchase is a cadmium sulfide photo cell which varies its resistance as a function of the light to which it is exposed. This item ordinarily sells for under $1.50. Both components can be obtained readily at any Radio Shack store.

A few minutes work yields the third piece of equipment. Use a short (15 cm) length of 4" pine (or any soft available wood). Drill a 1 inch (about 26 mm) hole nearly through from one end. This will hold a large test tube containing the sample.

Next, drill a hole at a right angle to the first, large enough to hold the photocell tightly, completely through from the side. Push the cell slightly into the hole and apply epoxy cement around the edges to hold it in place.

Attach the leads from the VOM to the two leads protruding from the photo cell. Your completed photometer should resemble the drawing below.


75-100 Watt Light Source
26mm Diameter Test Tube
Approximate 1 Inch Hole
Approximate 7/16 Inch Hole
CdS (Cadmium Sulfide) Photo Cell (Light-Variable Resistor)
VOM (Volt-Ohm Meter)
R

Materials

VOM (Volt-Ohm Meter)
CdS photo cell
Light source
4" X 4" pine block
 (15 cm long)
Epoxy

To use the photometer:

Set the selector on the VOM to read ohms (R X 1,Ω, or R). Shine a light through from the opposite side on to the photo cell. You should notice a deflection on the meter. By moving the position of the light source you should be able to cause the needle to travel "full scale". If it doesn't, try a larger bulb (ideally 75-100 watts).

When a test tube containing a turbid sample is inserted, light passage is reduced and a correspondingly smaller meter deflection should be noted. As the sample clears over time the needle will move upward.

NOTE: The VOM has several scales. If your students read the resistance scales (Ω, R) they should plot the data on semi-log graph paper. It is also possible to read any of the linear scales since the change is what is being measured. In that case, standard graph paper is used for data plotting. Since you are not strictly measuring per cent transmission with these scales, have your students relabel their data charts.

Other materials substitutions are also possible. If sea water is not available, a 3.5% salt (NaCl) solution will work well. If your laboratory has no balances, you may substitute volume measures (eg. teaspoon and ½ teaspoon measures). While the volumes determined this way are not exactly comparable, they are sufficient for the precision necessary in this experiment. You can increase the comparability by weighing a teaspoon of sand and determining the volume measure of silt necessary to equal the teaspoon weight.

Duplicate the activity pages. One set is recommended per student. This activity is best performed in small groups. It is possible for you to do this activity as a demonstration in which you perform the mechanical manipulations in front of the class while they make the observations and record the data. This approach is only recommended as an alternative to not doing the activity at all. It is much preferred to have your students perform the activity independently. Before your students begin briefly outline the procedure and demonstrate the use of the photometer. Notice that the uniformity of the time intervals between data collection depends upon the students taking the same amount of time to analyze each of the test tubes. In your discussion of the activity relate the findings on turbidity and the rate of sedimentation to the situation which obtains near a deep-sea mining system where large quantities of silt laden effluent are discharged into surface waters.

KEY

Text Questions

1. The amount of sediment in the water affects plant life by reducing the light available for plant growth.
2. A photometer is an instrument used to measure the amount of light passing through a substance.
3. The more / [✓ less] light measured by a photometer, the more cloudy (turbid) is the water. *[The correct answer is circled]*.

Analysis and Interpretation:

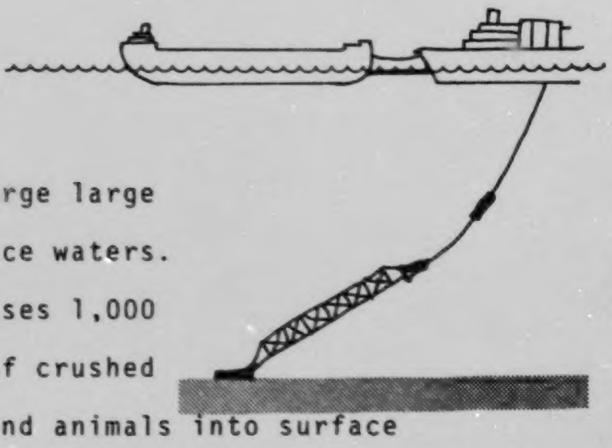
1., 2. Data will depend upon the experimental results.

3. a. Test tube D serves as a control against which the other tubes are compared. This is a good point to reacquaint your students with the classic components of an experiment.
    b. The variable that differs from test tube to test tube is the particle size.
4. While the answer depends upon the experimental results, test tube A would be expected to clear the fastest.
5. Again, while the answer depends upon the experimental results, test tube C would be expected to clear the slowest.
6. While the answer depends upon the data collected, the expected relationship would show that the larger the particle size, the faster the rate of clearing. Conversely, the smaller the particle size, the slower the rate of clearing.
7. In the area of a deep-sea miner, the smallest particles will have the longest affect on light transmission. The smallest particles are the last to settle out.
8. Your students may suggest a variety of ways in which deep-sea miners might reduce the negative effects of surface discharge including: filtering out of the fine sediments for disposal onshore or at depth; no discharge at all; adding chemicals to precipitate the sediments (this may simply move the problem to a different depth.; discharge at depth.

9. While your students may suggest a variety of possible dangers from adding alum, the "hint" included in the student text provides the direction the discussion should pursue. The possible danger lies in a chemically induced disruption of the bottom ecosystem. Use this question to point out the dangers of an "out-of-sight, out-of-mind" philosophy.
10. Scientists would be interested in lots of information including: baseline background data, quantities of sediment released, the depth of release, the currents in the area, the types of materials released, the kinds of plants and animals in the area, and a multitude of other parameters. Use this question to emphasize the need for sound ecological information before large-scale mining is begun.

KEY WORDS

alum
basis
control
deep-sea mining system
discharge
Erlenmyer flask
graduated cylinder
graph
horizontal
microscopic
negative
nodule
particle
percentage
photometer
plankton
relationship
scale
sediment
silt
transmission
turbidity
variable
vertical
vigorously



TO THE BOTTOM

Deep-sea mining systems discharge large amounts of material into the surface waters. Every working day each miner releases 1,000 metric tons of sediment, 50 tons of crushed nodules, and 51 pounds of plants and animals into surface waters. How long does it take for these materials to settle to the bottom? Microscopic ocean plants (plankton) need light to grow. The speed with which the waste water from the miner settles will have an effect on plant life in nearby waters. All of the animals in the area depend directly or indirectly on the plants for food. The growth of these marine plants, then, is very important to the life of the sea. In this activity you will see how the size of the activity effects the speed of settling.

1. How does the amount of sediment in the water affect plant life?

With a piece of equipment called a photometer we can determine how fast particles settle. As the name implies a "photo-meter" measures "photos". What are "photos"? "Photo" is the Greek word for light. A photometer measures light. How is light related to the speed with which particles settle? Particles in the water make the water cloudy. This cloudiness is called turbidity. The more cloudy the water is the less light that can pass through the sample. By watching the change in the light that passes through a water sample over time, we can determine how fast particles settle. Samples in which the sediments settle quickly will let light shine through quickly. Samples which remain turbid will not let very much light shine through.

2. What is a photometer?

3. The more/less light measured by a photometer the more cloudy (turbid) is the water. (*Circle the correct answer*)

Materials:

fine mud or silt

sand

test tubes (4)

test tube rack

glass marking pencil or labels

sea water

graduated cylinder (50 or 100ml)

balance

Erlenmyer flasks (4, 150ml or 250ml)

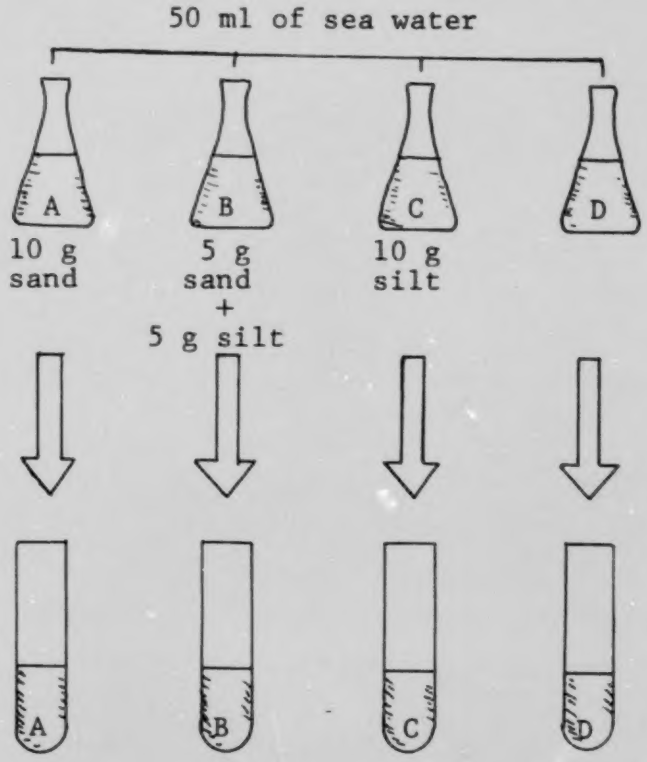
graph paper

clock with second hand

Procedure:

1. Obtain four Erlenmyer flasks and label them A through D.
2. Using a graduated cylinder add 50ml of sea water to each of the four flasks.
3. Weigh out a 10 gram sample of sand. Add the sand to Flask A.
4. Weigh a 5 gram sample of sand. Add the sand to Flask B.
5. Weigh a 5 gram sample of fine mud or silt. Add the silt to the sand in Flask B.
6. Weigh a 10 gram sample of fine mud or silt. Add the silt to Flask C.
7. Obtain 4 clear test tubes and label them A through D. Only handle the neck of the test tube. Mix the sediments in Flask A vigorously and add the contents of Flask A to test tube A. Repeat this procedure for Flasks B through D. Take care that all of the sediments from each flask get transferred to each test tube.

You have now completed the following procedures:



8. Place test tube D in the photometer. Adjust the photometer so that 100% of the light is transmitted (passes) through the water sample. Remove test tube D from the photometer.

9. Every two minutes you will record the turbidity of each test tube.

Shake test tube A vigorously. Place it in the photometer and immediately read the scale. This is the percentage of light that passes through test tube A at time interval 1. Record this number on your data chart. Enter the clock time in the first available space:

________, ________, ________, ________, ________, ________,

________, ________, ________, ________.

Add two minutes to this time and enter the time in the first available space:

________, ________, ________, ________, ________, ________,

________, ________, ________, ________.

10. Shake test tube B vigorously. Place it in the photometer and immediately read the scale. Record this number in the correct place on your data chart

11. Shake test tube C vigorously. Place it in the photometer and immediately read the scale. Record this number in the correct place on your data chart.

12. Shake test tube D vigorously. Place it in the photometer and immediately read the scale. Record this number in the correct place on your data chart.

13. When the clock reaches the time you recorded in the first space on the second set of blanks in step 9, repeat steps 9 to 13. All together you will make ten readings on each test tube.

14. After you have gathered your data, clean up your lab station.

Analysis and Interpretation:

1. Data Table: % Light Transmissions

Test Tube	Sampling Interval Number 1	2	3	4	5	6	7	8	9	10
A										
B										
C										
D										

2. Using the data collected, graph the results for each of the test tubes on a single graph, taking care to complete each line or curve before proceeding to the next. Your teacher will provide the proper graph paper and exact graphing instructions. Plot time on the horizontal axis and percent light transmitted on the vertical.

3. An experimental control is a sample which is treated exactly like the other samples except for one difference. The difference is called the variable. The variable changes in the experimental situations.

   a. Which test tube serves as a control against which the other tubes are compared?

   b. What is the variable that differs from test tube to test tube?

4. Which test tube cleared the fastest?

5. Which test tube cleared the slowest?

6. From your graph, what is the relationship between particle size and rate of clearing?

7. In the area of a deep-sea miner, particles of what size will have the longest affect on light transmission?

8. Suggest one way in which deep-sea miners might reduce the negative effects of surface discharge.

9. Alum is a material added to swimming pools to cause very fine particles to settle. What is one possible danger of using alum to cause mining wastes to settle more rapidly? (Hint: Where do the particles go when they settle?)

10. Because this experiment only checked a single variable, particle size, it may not be a good basis for predicting large scale changes in nature. What is one piece of information, aside from the rate of settling, which would help scientists make reasonable predictions about the effect of surface discharge from deep-sea miners?

WHALING

TEACHER BACKGROUND - December 5

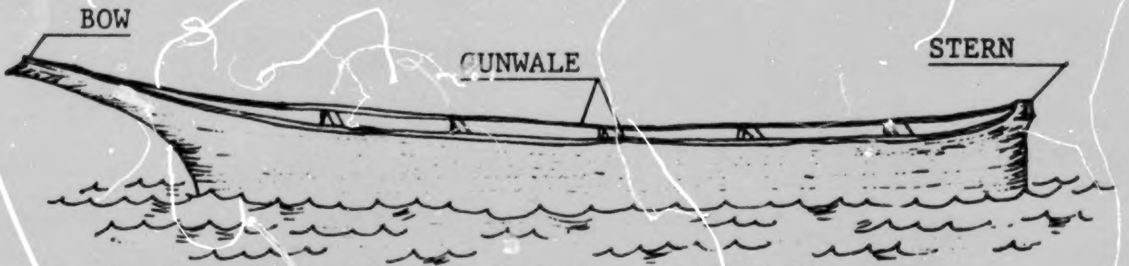
The story of man's interaction with the whale has been, and continues to be, a tale of nearsighted self-interest. "December 5" provides your students with a look at three major periods in whaling: Indian whaling, sailing whaling, and modern whaling. As a case study, whaling shows the complexity of ocean management problems. Biology, sociology, economics, and politics are all deeply involved in deciding the future of whale species. The following material gives your students an historical overview of the issues surrounding whale hunting. It cannot claim to be an in-depth look at a complicated issue. It does claim to be an introduction and, hopefully, it will arouse you and your students to further study and to action.

"December 5" is divided into four major sections: Indian Whalers, Sailing Whalers, Modern Whalers, and Regulating Whaling Nations. A separate review section is included for "Indian Whalers" and for "Sailing Whalers". A single, combined, review section for "Modern Whalers" and "Regulating Whaling Nations" is also included. These sections lend themselves to completion by individuals as homework or in-class assignments. The entire "December 5" is long for a single assignment. The one logical break occurs between "Sailing Whalers" and "Modern Whalers". Other teaching strategies are possible.

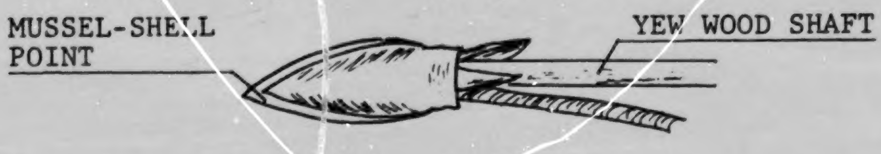
Duplicate the student text materials. One set is recommended per student. Your students will profit from a review and discussion of the materials presented in these sections. Consider supplementing this section with some of the high quality audio-visual materials now available. Film and video cassettes from the NOVA program entitled "Umealit: The Whale Hunters" are available from Time/Life. The program offers an incredible look at aboriginal bowhead whale hunting. Greenpeace, General Whale, and The Whale Protection Fund all offer free and low cost teaching aids and materials dealing with modern whaling and with whale preservation. Do not overlook your students as a resource for supplementary materials.

KEY

1. The lack of salmon has been cited as a major contributing factor to native whaling. The whale served as an important substitute for the protein not available from salmon.
2. Native whalers faced many difficulties including, but not limited to:
   a. cold water
   b. rough water
   c. no metal tools
   d. small boats
   e. the whale's powerful tail which could easily destroy the boat.
   f. the whale could pull the canoe far out to sea.
   g. stormy weather
3. Native whalers observed rituals and taboos before hunting the whales in the hopes that the spirits of the whales would look kindly on the whalers.
4. A correctly labeled North Coast Indian dugout canoe is shown below.



5. The three different "jobs" found in a native whaling crew were:
   a. captain or harpooner
   b. paddler
   c. steersman
6. A correctly labeled harpoon head is shown below.

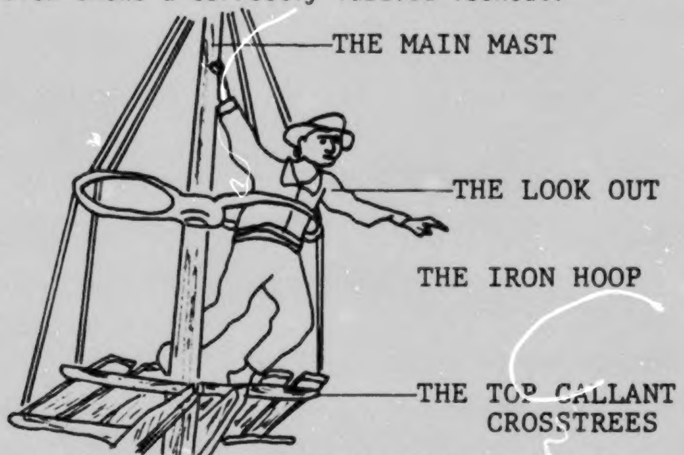


7. The hide floats were used to keep the line afloat near the surface. Aside from providing a method for keeping the line in sight, the floats may have increased the drag on the swimming whale.

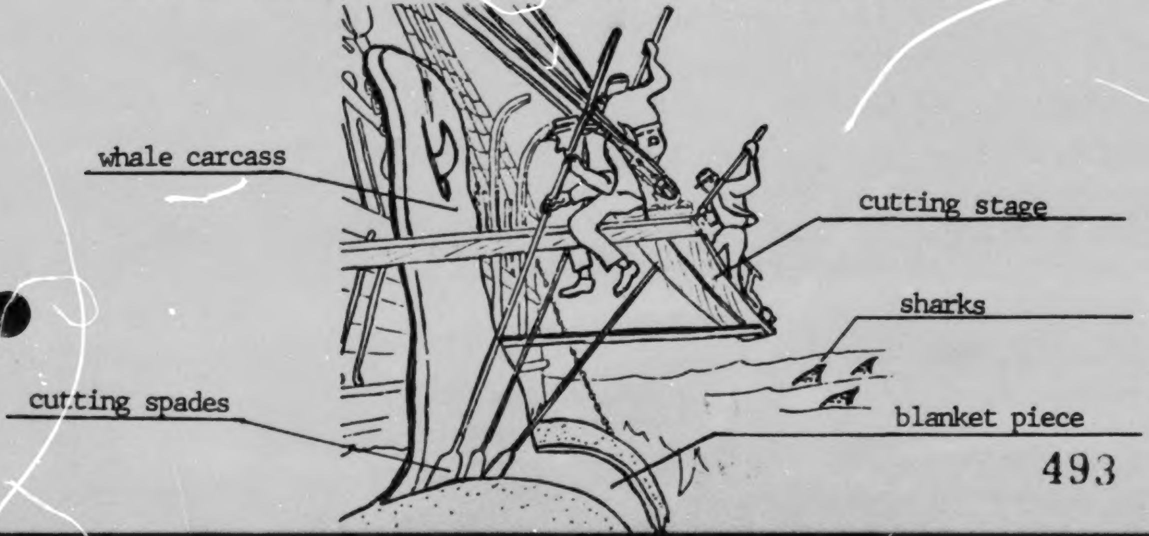
8. After a whale was harpooned, the steersman turned the canoe away from the whale's giant flukes (tail).
9. The choice pieces of blubber were awarded to people by rank and by the role they played in the hunt. The elders of the tribe and the harpooners usually received the select pieces.
10. The whale was used completely. The blubber was rendered to remove the oil. The cooked blubber was dried and eaten. The oil was used as a food dressing. The bones provided tools and building materials.

Sailing Whalers

11. The drawing below shows a correctly labeled lookout.


THE MAIN MAST
THE LOOK OUT
THE IRON HOOP
THE TOP GALLANT CROSSTREES

12. The boatsteerer was the crew member who threw the harpoon.
13. A "Nantucket sleigh ride" occurred when a harpooned whale swam across the sea at great speed while towing behind the whalers in their small whaleboat.
14. The crewman that harpooned the whale was / [✓ was not] the same person who killed the whale. The correct answer is circled.
15. The drawing below shows a correctly labeled "cutting in".


whale carcass
cutting stage
sharks
cutting spades
blanket piece

16. This question involves some thought by your students. Basically, whalers could hold more oil than blubber. As a result, rendering on-board increased the value of the cargo. It also decreased the need to return to shore stations. The decreased connection with shore stations was important because it allowed whalers to venture farther from shore. The ability to go farther was important because the whalers had effectively slaughtered the near-shore whales. A second factor also came into play. As the Nantucket crews began to whale in latitudes nearer the tropics, they found the blubber turned rancid in the heat. The rancidity reduced the value substantially. Rendering the blubber on board solved this problem. From the above, it should be evident that ship-board try works were a major breakthrough for the sailing whalers.

17. Three products the Nantucket whalers derived from whales include:
    a. spermaceti for lubricating oil and smokeless candles.
    b. fuel oil from blubber
    c. teeth for scrimshaw.

    A fourth product not mentioned but of great value in the later days of sailing whalers was the baleen used in corset stays, umbrellas and a variety of other commodities.

18. Shore whalers hunted blue / [✓ gray / humpback] / fin whales in waters near the coast. The correct answers are circled.

19. Shore whaling lasted for only about 30 years.

Modern Whalers

20. Three factors which threatened to end the whaling industry in 1880 are:
    a. whalers had hunted the small and slow moving whales into extinction or near extinction.
    b. kerosene replaced whale oil as a fuel for lamps.
    c. a large number of whaling ships were crushed by Arctic ice.

21. Blue whales were not hunted by sailing whalers because the speed of the blue whales let them out-distance the sailing ships.

22. a. Before the blue whale could be hunted the following three problems had to be solved:
    - I. The fast speed of the whales had to be matched by a chase vessel.
    - II. A harpoon capable of killing the giant animal had to be created.
    - III. Dead whales had to be kept from sinking.

    b. Svend Foyn, a Norwegian captain, solved these three problems.

23. The major factor that made whalers look for whales in Antarctic waters was that the whalers had destroyed the blue whale in the Northern Hemisphere. Other factors your students may mention spring from the above and will most likely deal with economics.

24. About three million pounds of krill are needed to make a 150 ton whale. A convenient way to set up the problem is shown below:

$$\frac{150 \text{ tons}}{\text{whale}} \times \frac{2000 \text{ pounds}}{\text{ton}} \times \frac{10 \text{ pounds krill}}{1 \text{ pound of whale}} = 3{,}000{,}000 \text{ pounds krill}$$

Note that this simplistic solution does not take into account the pounds of krill required to maintain the whale as it grows.

25. Your students may have a variety of suggestions. Basically, an agreement, between all whaling parties, which limited the number of whales killed to a number which the whale population could sustain without an overall annual reduction in numbers would have protected the population while still providing whalers with income. The whale is a classic example of a "common good". Since no one owns the whale, there is no incentive not to take all you can right now. After all if I let a pregnant cow swim away, there is no guarantee that I'll get to catch her after she has given birth. In fact, I can be sure (or so I'll think) that you'll kill her as soon as you see her. So "better me than you" spelled the doom for several whale species. It may spell the doom for several more.

26. A factory ship is a large ship that accompanies the whaling fleet. It has a slipway by which whales can be hauled onto the deck for processing. It has all of the equipment necessary to completely process the killed whales.

Regulating Whaling Nations

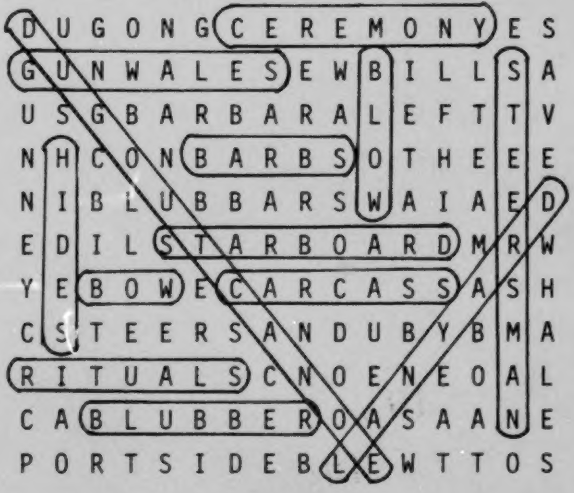
27. Your students should be able to define "police powers" by using context clues from the text sentences surrounding the term. Police powers refer to the powers (ie. the right and strength) necessary to enforce an agreement or law.
28. The IWC is the International Whaling Commission, a group made up of representatives from whaling nations. The IWC sets minimum length requirements, season dates, and kill quotas.
29. This question asks for an opinion. As such, there are no right or wrong answers. The blue whale is no longer an important commercial whale because of its drastically reduced numbers.
30. The chart included indicates that the following species may be hunted at higher levels (ie. they are classified as "initial species").
    a. Bryde's
    b. Minke (but only in the Southern Hemisphere and a part of the North Pacific)
    c. Sperm (but only in part of the Southern Hemisphere and part of the North Pacific)
31. a. The list of products the United States imports from Japan and the Soviet Union is long. Those most common to your students will likely be: cars, cameras, stereos, televisions and other electronic items from Japan and vodka from the Soviet Union.
    b. Answers will vary but most will probably own some of the items listed.
    c. Since Japan makes far more money exporting cars and electronic equipment than it earns from whaling, the boycott theory states that it will be to the advantage of Japan (and the Soviet Union by analogy) to stop whaling and lose the larger export income. There is some evidence that the boycott technique coupled with advertisements alerting the people of the plight of the whale has had an effect on the Japanese view toward whaling. Unfortunately, part of the new view involves Japanese financed "front" whaling companies (called Pirate whalers since they do not recognize IWC regulations) operating out of Peru, Korea and other nations.

32. Today whale oil finds its use in foods, detergents, shoe polish and special lubricants.
33. Most whale products are sold in Japan and Europe.
34. [✓ All] / None of the products listed can be derived from sources other than whales. The correct answer is circled.
35. Your students will likely have various interpretations of the statement "Whales are an indicator of the health of the world's living systems". The essence of this statement might be summed up by saying that a world which can't support populations of whales will not be able to long support populations of man. In your discussion of this question emphasize the fact that all living creatures are interrelated and what affects one, ultimately affects all.

KEY

Keys for the reinforcement activities "Indian whalers - Find that Word", "Sailing Whalers - Save My Story!", and "Modern Whaling/Regulating Whaling Nations - Causes and Effects" follow on the next pages. All three activities reinforce the text while treating different reading skills. "Indian Whalers - Find that Word" builds vocabulary skills. "Sailing Whalers - Save My Story!" stresses sequencing skills. Caution your students to read the entire text selection before making their choices. "Modern Whaling/Regulating Whaling Nations - Causes and Effects" treats the organizational scheme found in much scientific writing.

Indian Whalers - Find that Word



D U G O N G C E R E M O N Y E S
G U N W A L E S E W B I L L S A
U S G B A R B A R A L E F T T V
N H C O N B A R B S O T H E E E
N I B L U B B A R S W A I A E D
E D I L S T A R B O A R D M R W
Y E B O W E C A R C A S S A S H
C S T E E R S A N D U B Y B M A
R I T U A L S C N O E N E O A L
C A B L U B B E R O A S A A N E
P O R T S I D E B L E W T T O S

Sailing Whalers - Save My Story!

A.

Text page	Illustration
1.	B
2.	A
3.	E
4.	C
5.	D

B.

Illustration	Order
A.	Third
B.	Fifth
C.	Fourth
D.	First
E.	Second

C. Obviously, there are no "right" answers to this section. Reward creativity to help make this an enjoyable activity.

Modern Whaling/Regulating Whaling Nations - Causes and Effects

	Causes		Effects
C 1.	Pennsylvania oil wells produced kerosene.	A.	The International Whaling Commission was created.
F 2.	Svend Foyn built the first steam powered whaler.	B.	By 1925, only 9 humpback whales could be found to kill.
D 3.	Svend Foyn pumped compressed air into dead whales.	C.	Whale oil was replaced as a fuel for lamps.
I 4.	Svend Foyn's whaling techniques were very successful.	D.	The rorqual whales which sink after death could be hunted.
K 5.	Krill reproduce explosively.	E.	Many whales face extinction.
B 6.	Whalers in the Antarctic picked the humpback whale.	F.	The fast swimming rorqual whales could be chased
J 7.	Whalers killed all of the whales that bred near Antarctic shore stations.	G.	Groups have placed economic and political pressure on whaling countries.
A 8.	Marine scientists predicted that the whale would soon become extinct.	H.	Protection for the various species of whales has come too little and too late.
H 9.	IWC decisions are based on the opinions of the member nations.	I.	By 1903, the blue whale was no longer found in the Northern Hemisphere.
G 10.	Many people feel that the IWC alone cannot save the whales.	J.	Factory ships were developed to accompany the fleet into the Antarctic ocean.
E 11.	Whales are leaving the sea in tanks, cans and sacks.	K.	Whales that fed on krill were very numerous.

KEY WORDS

Indian Whalers

antler
ashore
barbs
blow
blubber
bow
canoe
carcass
ceremony
down
dressing
dugout
flank
flare
flipper
float
fluke
gunwales
harpoon
hides
inflated
lanyard
lines
native
occasional
paddler
port
pursued
rank
rituals
role
saddle
spirits
starboard
steersman
stern
taboos
tendon
upswept
whaler
yew wood

Sailing Whalers

abandon
adrift
bail
bible leaves
blanket pieces
blubber
bluff
boatsteerer
boat header
caldron
carcass
clumsy cleat
cove
cutting in
cutting stage
fated
friction
harpoons
hold
horse pieces
lance
lash
loggerheads
lookout
lubricate
mast
moorings
Nantucket
Nantucket sleigh ride
precipitous
premises
profane
putrid
quay
sacrifice
schooners
shore whaling station
spade
spermaceti
stench
strained
suffocating
top gallant crosstrees
try works
whaler

Modern Whalers

adapted
Antarctic
Arctic
body cavity
bountiful
cannon fired harpoon
charge
compressed air
deck
expedition
explosive
extinction
factors
factory ships
fleet
hauled
industry
krill
motorized
Northern Hemisphere
population
process
rorqual
shore whaling stations
skinned
slipway
Southern Hemisphere
steam engine
Svend Foyn
turbulent
wasteful
whalers
whaling grounds

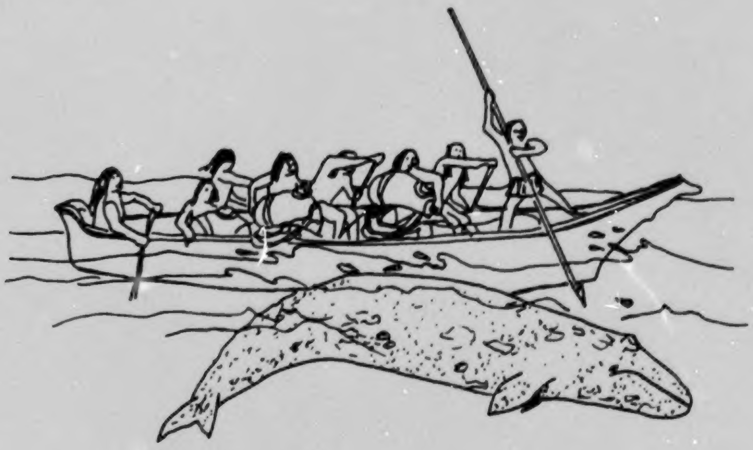
KEY WORDS - Continued

Regulating Whaling Nations

administrator
agreement
baleen
blubber
calf
catch statistics
commercial
conservation
controls
economic
edible
enforce
extinct
extract
fillets
flippers
flukes
harvested
indicator
initial
International Convention for the Regulation of Whales
Internation Whaling Commission (IWC)
Japanese
police powers
political
population
porous
ports
preservation
products
profitability
protected
protection
quota
races
recovery
residue
rorqual
scrimshaw
slaughter
souvenirs
Soviet
species
straits
survival
sustained
tankers
whaling

DECEMBER 5

Swimming, breathing, swimming, breathing, the move south continues. Our whale is now within sight of Monterey, California. Even her oldest memories can not reach back to the years that nearly spelled the end of her kind. In 1851, Monterey became the first shore-whaling station on the coast of California. Within thirty years so few gray whales could be found near shore that the shore stations all closed down. How could man have had such a great effect on the gray whale?



Indian Whalers

Long before the Portuguese arrived in Monterey, people of the coast hunted the whale. Most Indian tribes used the whale carcasses which, occasionally, washed ashore near their villages. These giant dead whales provided products from oil to ivory. Not all of the native peoples were content with the occasional dead whale nature provided.

Several tribes on Vancouver Island's west coast (the Moachat, Ahousat, and Clayoquot) and the ocean coast of Washington (the Makah, Quillayute, and Quinault) actively hunted the whale.

1. Native whalers lived in areas with no important salmon streams. Could this lack of salmon help explain why the Indians became whalers? How?

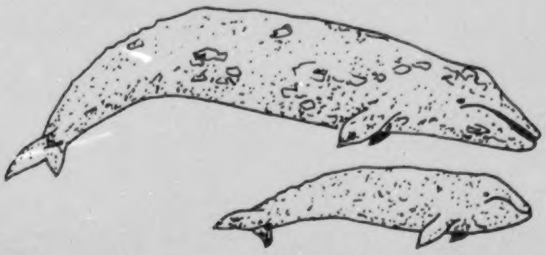
Native whalers hunted the California gray whale and the humpback whale. Young whalers pursued killer whales as a test of skill. Conditions facing the whale hunters were difficult. To lessen some of the difficulties, native whalers hunted during the warm months of spring and summer. The whaling season began with the hunting of California gray whales in the spring.

2. What were two difficult conditions faced by native whalers? (Hint: Think of yourself in a small boat)

   a.

   b.

To native whalers, hunting was more than a job. Hunting was their life. Long before the actual hunting took place, the whalers and their wives had many rituals to perform. They also had many taboos, or things they could not do, to observe.

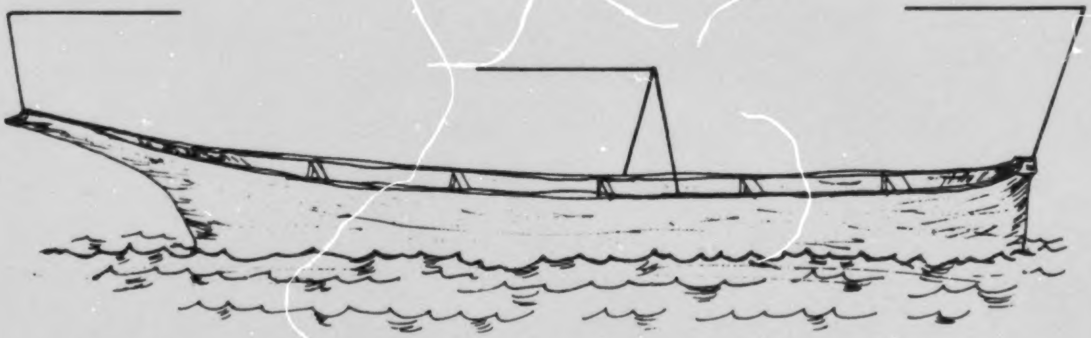


The rituals and taboos were performed so that the spirits of the whales would look kindly on the whalers. The hunters understood the danger of the hunt. They also understood and respected the importance of the whale populations.

3. Why did native whalers observe rituals and taboos before hunting whales?

The day of the hunt has arrived. Eight men move down the beach toward their boat. The red cedar dugout lies in readiness. The canoe has a graceful, upswept bow or front. The stern, or back, is also carefully styled. The gunwales, or sides, flare outward to turn away the waves. The sleek boat cuts the water with little effort.

4. The picture below shows a north coast Indian dugout canoe. Label the drawing by placing the correct name in the blanks.



The whaling crew reaches the boat. The captain or harpooner steps into the bow. The steersman climbs to the back of the canoe. The six paddlers push the canoe into deeper water and climb aboard. As the paddlers move the canoe away from the shore, another crew climbs into a second canoe. While the canoes move away from shore, the captains check their equipment. The harpoon, lines and floats all lay on the starboard side (the right side when facing forward). The lines, or ropes, are neatly coiled.

5. What were the three different "jobs" found in a native whaling crew?

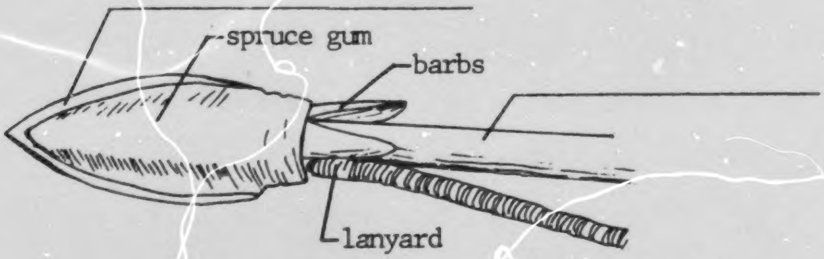
   a.

   b.

   c.

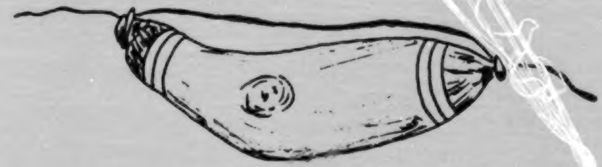
The paddlers pull the boat into deeper water. The captain gives his harpoon a last minute check. The harpoon has a yew wood shaft three fathoms (18 feet) long. The head has a mussel-shell point and antler barbs. He checks the lanyard, or rope made of twisted whale tendon, which is attached to the head. At the end of the short lanyard, he checks the line (rope) made from cedar branches. The cedar branch line ends where a cedar bark line begins.

6. The drawing below shows a north coast harpoon head. Label the drawing by placing the correct name in the blanks.



North Coast Indian Harpoon

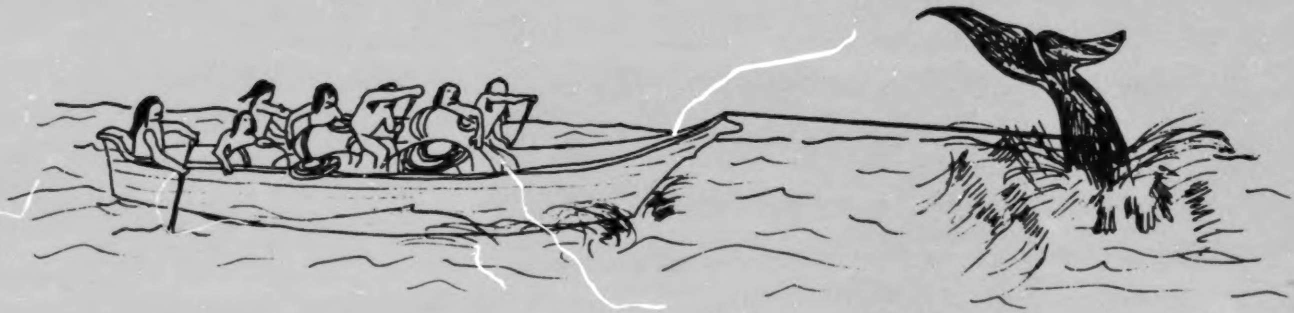
The paddlers spot the "blow" of a California gray whale. The "blow" is water vapor from the whale's breath. The captain checks the floats which will keep the lines near the surface. The floats are the inflated hides of hair seals. One float is attached to each section of line.



FLOAT

7. What was the role of the floats in north coast native whaling?

All is ready. The paddlers are pulling toward the gray whale. They turn the canoe and approach the whale from its left flank (side). The captain stands in the bow, harpoon in hand. The canoe and the giant whale are side by side. The whale begins to sound (dive). At the same moment, the captain sinks the harpoon deeply into the flesh behind the flipper of the great whale. The canoe comes alive with action. Paddlers on the starboard side handle the lines to keep them free. The port paddlers and steersman turn the canoe away from the whale's giant flukes (tail). The captain readies a second harpoon. Two of the paddlers blow up more floats and lay a second line. The remaining paddlers pull in chase of the whale.



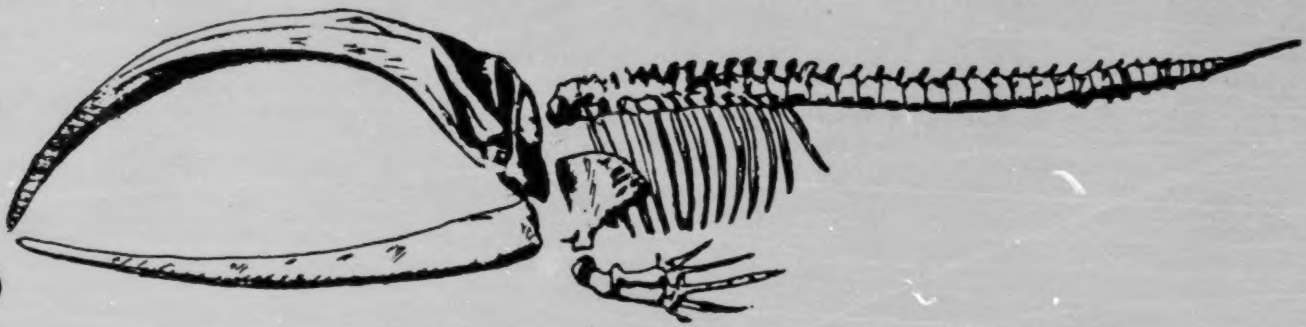
Now the crew of the second canoe moves into position. Their captain plants the second harpoon. The two canoes add floats and lines as the whale pulls them through the water. Songs and prayers are used to turn the whale toward shore. The whale slows. With a final dive he dies.

8. After a whale was harpooned, what was the job of the steersman?

The whale is dead but work still remains. The paddlers stroke to tow the carcass home. Finally, the dead whale is floated ashore at high tide. In thanksgiving, the whale is received in a ceremony as an honored guest. The carcass is decorated with eagle down (feathers) to please the spirit of the whale.

Choice pieces of blubber are cut off the whale. They are given to people according to rank and also to the role they played in the hunt. The first piece cut is the oil-rich saddle or hump. As a special honor, this piece is hung in the captain's house. The saddle is an important piece. The captain will carve its likeness in wood. The carving will hang permanently in the captain's house.

9. Which people in the tribe received the choice pieces of blubber?



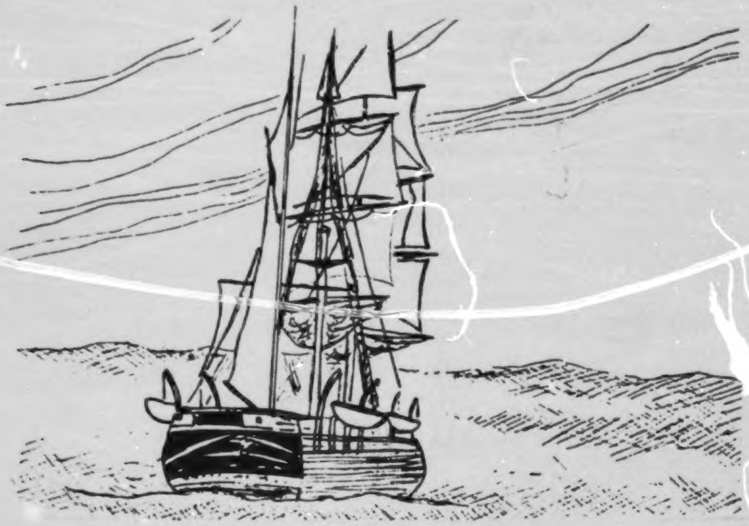
The tribal members now settle down to using the whale. Oil is removed from the blubber. This oil is used as a dressing for dried fish and for berry cakes. After the oil is removed, the dried blubber is eaten. The bones provide tools and building materials. In a real sense, the whale gives his spirit to the community.

The life of these north coast Indian peoples was tied directly to the whale. The arrival of the Portuguese in Monterey signaled the beginning of another era in whaling.

10. How was the whale used by north coast Indian peoples?

Sailing Whalers

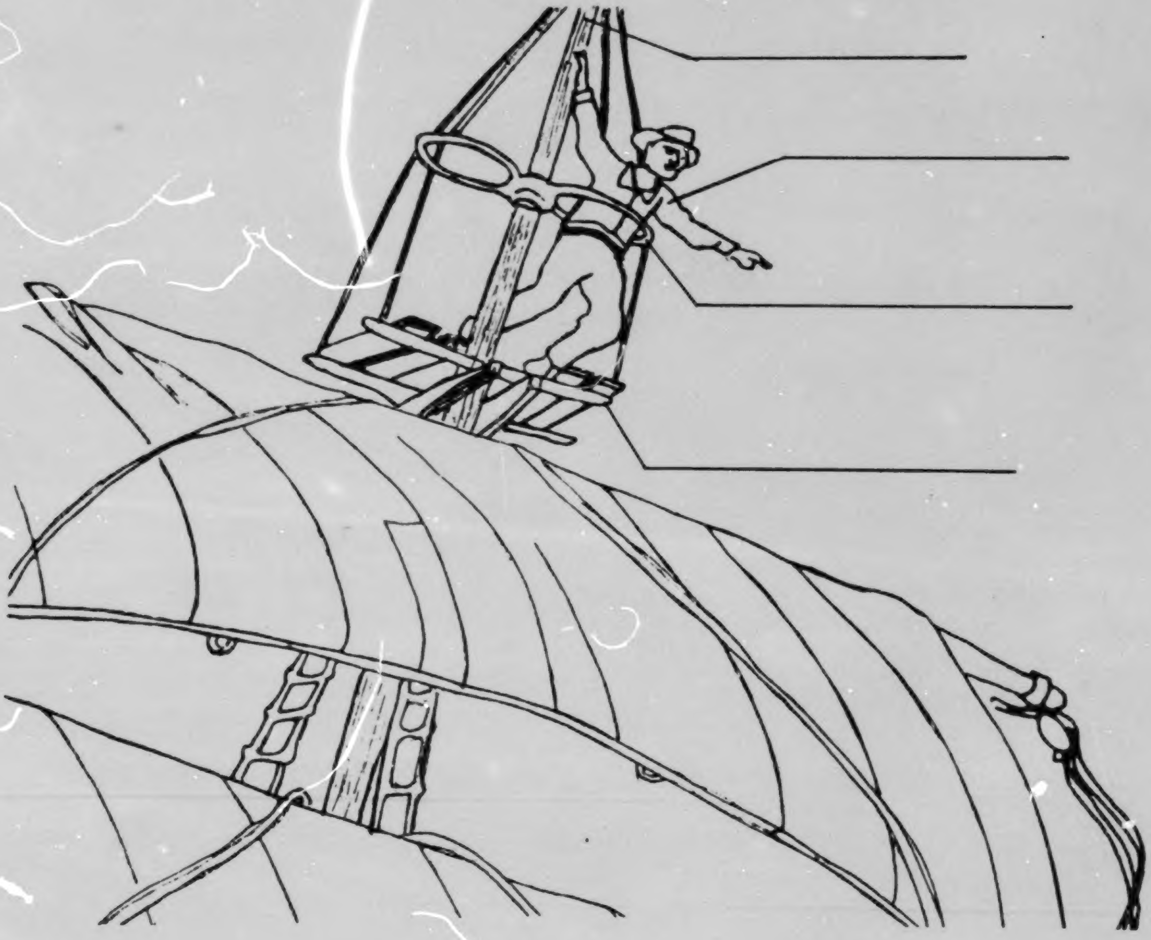
In 1851, a small group of Portuguese from the Azores Islands of the Atlantic arrived in Monterey, California. This group built the first shore whaling station in California. But they were not the first non-native whalers in the Pacific. By 1746, whaling schooners from Nantucket, Massachusetts were cruising to Africa and the South Atlantic. In 1787, the first whaler to sail around Cape Horn and enter the Pacific Ocean waters sailed from Nantucket. By 1820, Nantucket whalers were sailing the waters of the North Pacific. What was life like on a Nantucket whaler?



It is hard to imagine that men ever dared to attack the whale with harpoons thrown from small wooden boats. For pure size and power, the whale has no rival. But for the Nantucket whaleman, this dangerous combat was a way of life.

When under sail, a man was always posted as lookout on two small boards called the "top-gallant crosstrees." The top-gallant crosstrees" were fastened to the main mast of the ship. He was steadied by a waist-high iron hoop attached to the mast a hundred feet above deck. He swayed back and forth for two dizzying hours before being relieved.

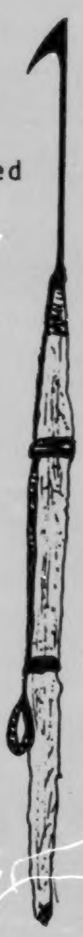
When a whale was sighted, the lookout cried, "A-a-a-ah blows! Thar she blows!" The ship below him erupted into action. His long drawn out cry sent a thrill through every man in the ship.



11. The drawing above shows a look out on a Nantucket Whaler. Label the (a) top gallant crosstrees, (b) the look out, (c) the iron hoop, and (d) the main mast.

Small boats with crews of six were lowered. The chase had begun! With much colorful and downright profane yelling, the boatsteerer urged the crew onward toward the spot. The crew pulled toward the spot perhaps 3.2 km (about 2 miles) away, where they expected the whale would reappear. When the whale came up for air, the whaleboats would be waiting. "Pull lads! Put your back into it, me heroes!" As the boat approached throwing range, the boatsteerer stood up with his feet on the forward platform. He braced his knee against the "clumsy cleat" at the bow of the boat. With all his might, he harpooned the whale.

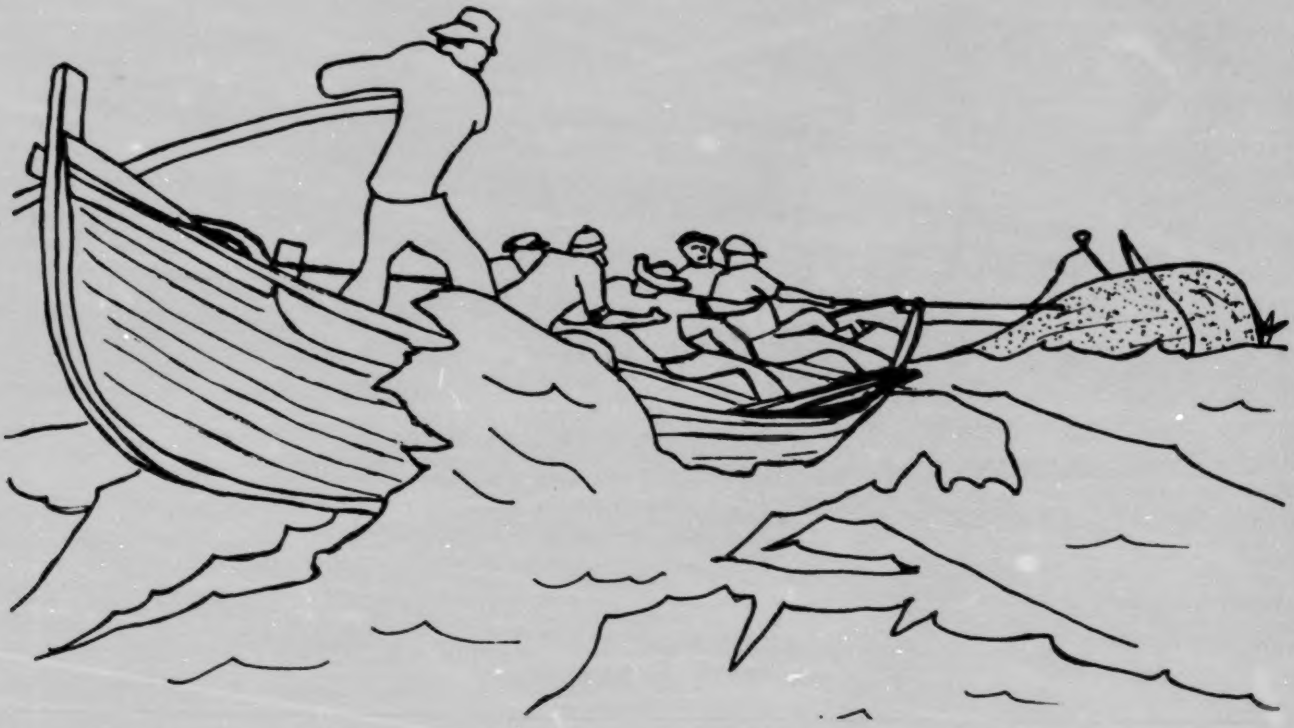
12. Which crew member threw the harpoon?



Boat and whale were then fated to fight it out. The whale might dive or lash his tail with thundering blows that could smash the boat to splinters. Sometimes the crew was forced to abandon the boat. They had to sacrifice the catch to save their lives. Sometimes the whale swam across the sea with terrifying speed. The whalemen were towed on what was called a "Nantucket sleigh ride." The line whipped out of the tubs and whistled around the loggerheads so fast that the men poured water over the rope to keep it from being set on fire by friction.

13. What was a "Nantucket sleigh ride"?

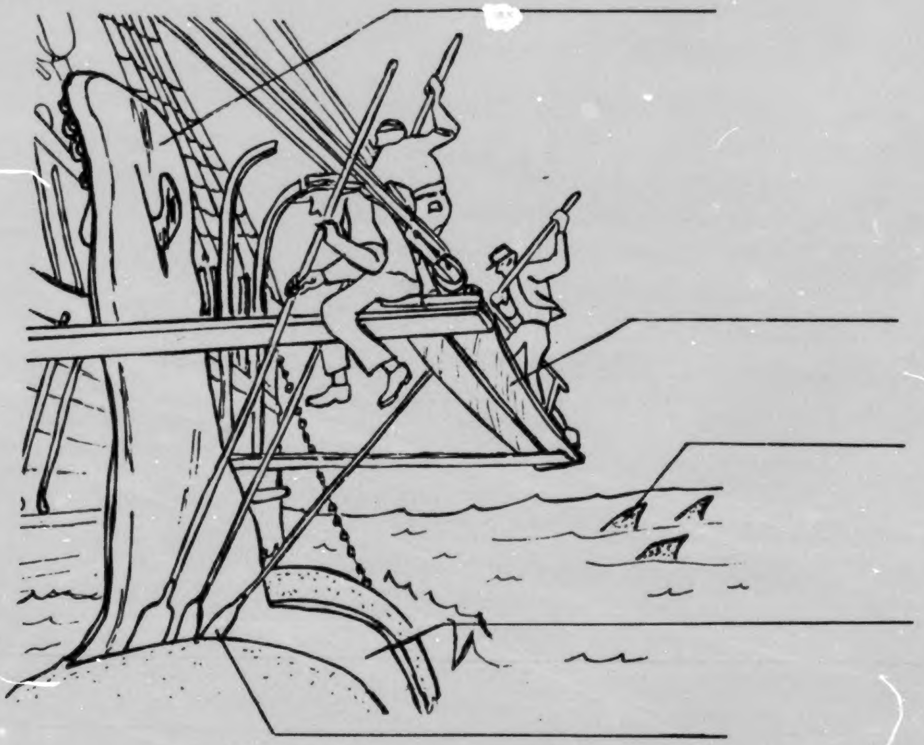
The whale towed the boat until the whale tired in its attempt to escape. Exhausted it lay in the water alongside the boat. The officer-in-charge or boat header would change places with the boatsteerer and kill the whale with the plunge of a long iron lance.



14. The crewman that harpooned the whale was / was not the same person who killed the whale. (Circle the correct answer)

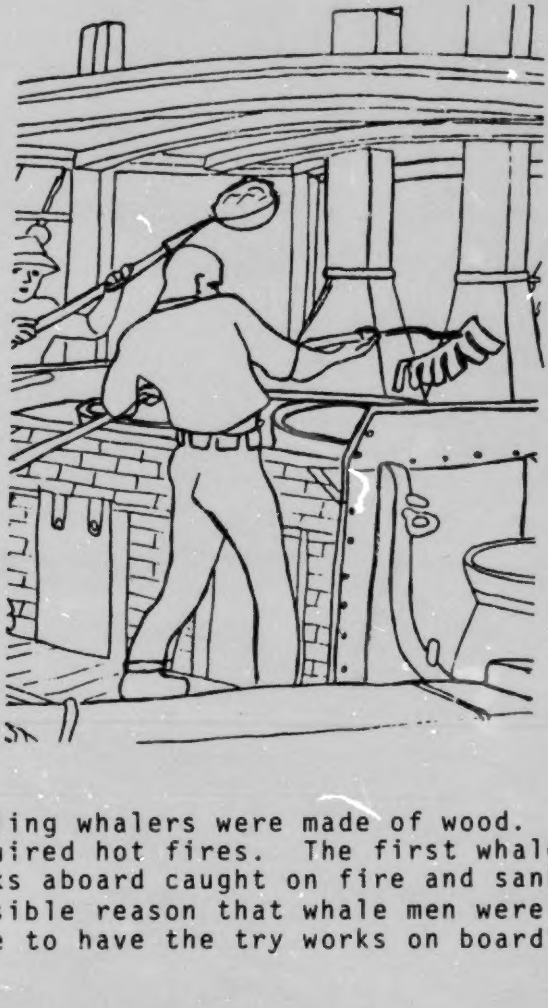
The enormous carcass was towed back to the ship. The "cutting in" or removal of the blubber began.

The seamen stood on a narrow platform called a cutting stage. From the stage, they labored with sharp spades. First they separated the whale's head from the body. The blubber was then cut in a continuous strip as the body rolled over and over. As the men worked, the carcass was often surrounded by sharks. Large sections of blubber "blanket pieces," were lifted aboard and stored temporarily in the ship's hold. When all the blubber had been removed, the stripped carcass was set adrift to be torn apart by the sharks.



15. The drawing above shows the crew of a whaler "cutting in". Label the (a) cutting stage, (b) cutting spades, (c) blanket piece, (d) whale carcass, and (e) sharks.

The blanket pieces were sliced to smaller "horse pieces." The horse pieces were further minced into smaller "bible leaves" resembling open pages. These pieces were thrown into the "try-works." The "try-works" were large brick furnaces containing two huge iron caldrons (pots) in which blubber was boiled. The men labored day and night for several days at the roaring try-works. The stench was incredible and the smoke suffocating. As the oil rose to the tops of the kettles, it was scooped off, cooled, strained, and stored in barrels. Each barrel contained 119 liters.



16. Sailing whalers were made of wood. The try works required hot fires. The first whalers with try works aboard caught on fire and sank. What is one possible reason that whale men were willing to risk fire to have the try works on board?

Sailing whalers killed a variety of whales. Even so, the sperm whale was the prefered prey. The real treasure was the head of the sperm whale. The case located on the upper part of the head contained up to 1,892 liters of high grade oil. This oil, called spermaceti, was used to make smokeless candles and to lubricate watches and other delicate machinery. The spermaceti was bailed out with buckets and stored in specially marked barrels.

Sperm whales' teeth were also valuable. When turned into art works, they found a good buyer's market. Pulling whales' teeth was tricky. But the whalemen had mastered the process and the teeth popped out like peas from a pod.

After the teeth were removed and all the oil and spermaceti had been stored in barrels below deck, the whalemen spent several more days scrubbing the ship clean. The hunt for more whales would then resume.

17. What were three products the Nantucket whalers derived from whales?

    a.

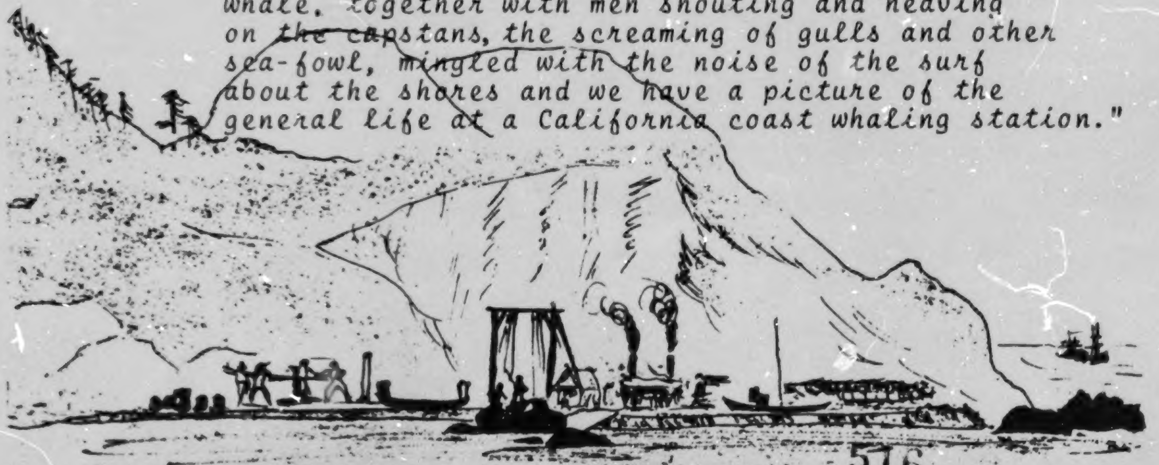
    b.

    c.

Shore whalers

How did the shore whaling stations fit into the picture? The shore stations existed by hunting whales close to shore. The Monterey station was located in a protected cove. The small whaling boats were launched from the cove. The whalers hunted humpback and California gray whales. Captain Charles M. Scammon gives us an eye-witness description of life at the Monterey station.

> "The one which most interested us is half-hidden in a little nook, on the southern border of the Bay of Carmel, just south of Point Pinos. Scattered around the foothills, which come to the water's edge, are the neatly whitewashed cabins of the whalers, nearly all of whom are Portuguese, from the Azores or Western Islands of the Atlantic. They have their families with them, and keep a pig, sheep, goat, or cow prowling around the premises.... It is a pleasant retreat from the rough voyages experienced on board the whale-ship.
>
> Under a precipitous bluff, close to the water's edge, is the station, where, upon a stone-laid quay, is erected the whole establishment for cutting-in and trying-out the blubber of the whales... Nearby are the try-works, sending forth volumes of thick, black smoke from the scrap-fire under the steaming cauldrons of boiling oil. A little to one side is the primitive storehouse, covered with cypress boughs. Boats...swing at their moorings in the bay. Seaward, on the crest of a cone-shaped hill, stands the signal-pole of the lookout station. Add to this the cutting at the shapeless and half-putrid (rotten) mass of a mutilated whale, together with men shouting and heaving on the capstans, the screaming of gulls and other sea-fowl, mingled with the noise of the surf about the shores and we have a picture of the general life at a California coast whaling station."



The next 20 years, until 1871, saw a rapid increase in shore whaling. The shore whalers were effective. By 1880, California gray whales and humpback whalers became too scarce to be hunted profitably. The shore whaling stations had hunted themselves out of business.

18. Shore whalers hunted blue / gray / humpback / fin whales in waters near the coast. (Circle the correct answer(s))

19. Shore whaling lasted for only about _______ years.

Modern whalers

By 1880 the entire whaling industry was in serious trouble. The sailing whalers, like the shore whalers, had hunted the small and slow whales to near extinction. Only the large, fast swimming whales remained. The drilling of America's first successful oil well in Pennsylvania in 1859 dealt another blow to whaling. The well produced kerosene. Kerosene was cheap and smokeless when burned. It soon replaced whale oil as the fuel for lamps. In 1871, 33 ships were caught in Arctic ice off the northern whaling grounds. The ships had to be abandoned and were crushed by the ice. In 1876, another dozen were lost in the ice. The fleet was being destroyed.

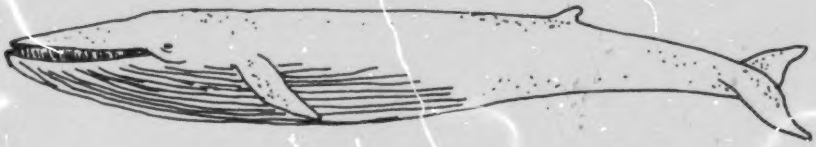
20. What are three factors which threatened to end the whaling industry in 1880?

    a.

    b.

    c.

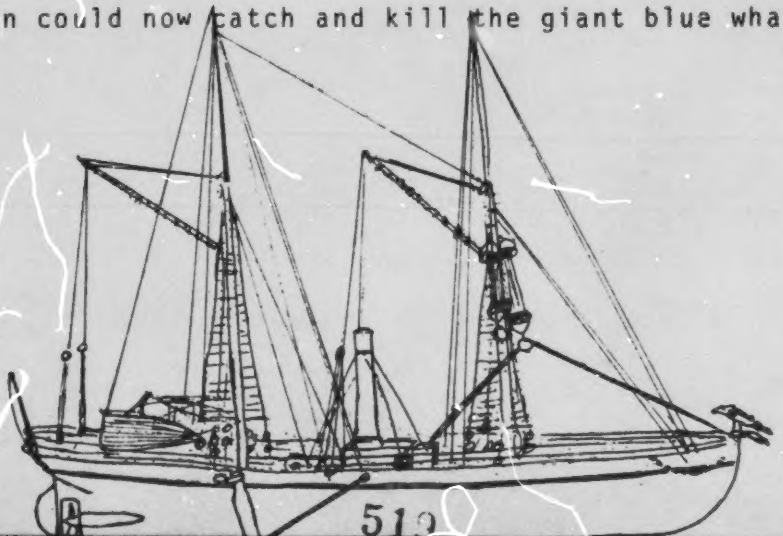
Into this picture sailed, or rather motored, Svend Foyn. Svend Foyn was a whaling captain from Norway. Foyn had led many whaling expeditions to the Arctic. He saw the right whales decrease in number. He saw the whale catches decrease from year to year. He also saw the blue whales and the other fast swimming rorqual whales. He saw their great numbers. He saw that their speed let them out-distance the sailing ships.



21. Why were blue whales not hunted by sailing whalers?

In response to what he observed, Foyn adapted the steam engine to his whaling ship. The first motorized whaling ship had been born. The steam powered ship could maintain speeds of seven knots (over 8 mph). The fast swimming rorquals could now be chased. Two other problems still remained to be solved. The harpooning techniques used on the slower moving whales could not be used on the rorquals. Secondly, unlike right whales, the rorquals sink after death.

Svend Foyn solved the first problem by building a cannon-fired harpoon. The harpoon had an explosive head. The heavy harpoon was fired into a whale. Within seconds, the black powder charge in the head exploded inside the whale. Svend Foyn could now catch and kill the giant blue whale.

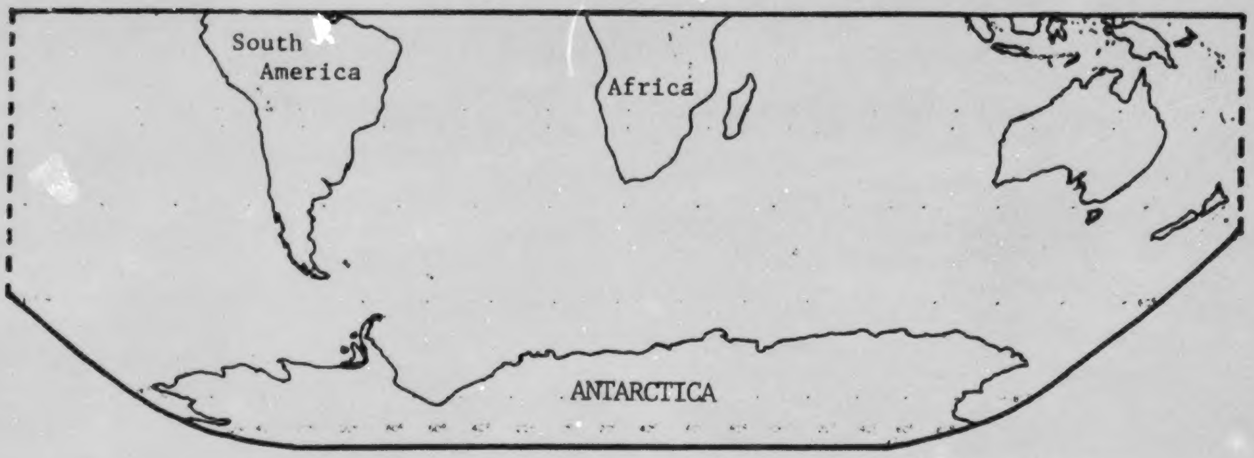


The problem of keeping these large whales afloat still remained. To solve this problem, Svend Foyn pumped compressed air into the body cavity of the dead whale. The large, fast-swimming whales were no longer safe from the hunt.

22. Sailing whalers did not hunt the fast-swimming blue whale.
    a. What three problems had to be solved before the blue whale could be hunted?
       I.
       II.
       III.
    b. Who solved these problems?

By 1888, Norwegian whalers were killing a thousand blue whales a year within a short distance of their shores. Foyn's technique was so effective that by 1903 the blue whale was no longer found in the Northern Hemisphere. Once again the whalers had put themselves out of business.

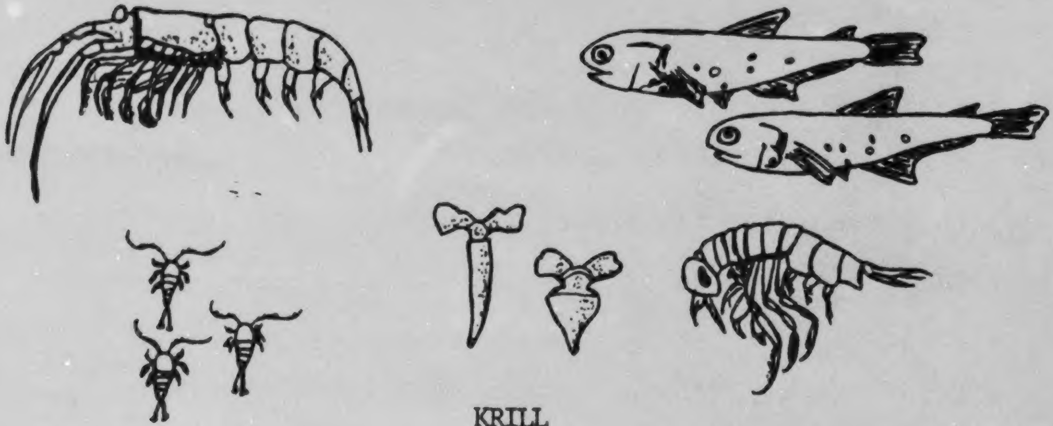
Having destroyed their livelihood in the Northern Hemisphere, the whalers looked south. The waters off Antarctica are protected by the world's stormiest weather. Few early whalers had sailed in Antarctic seas. Modern whalers in 120-foot long steam powered ships turned into the turbulent Antarctic waters.



SOUTHERN HEMISPHERE

23. What was one factor that made whalers look for whales in Antarctic waters?

The first Norwegian fleets to sail in the Antarctic returned home with reports of whale herds of tremendous size. Hundreds of thousands of huge fin, blue and humpback whales lived in the Antarctic. The whales fed on millions of tons of "krill". Krill are shrimp-like animals that reproduce explosively during the Antarctic summer. Early visitors to the whaling grounds told of seeing hundreds of blue whales from a lookout at one time. The hunt was on.



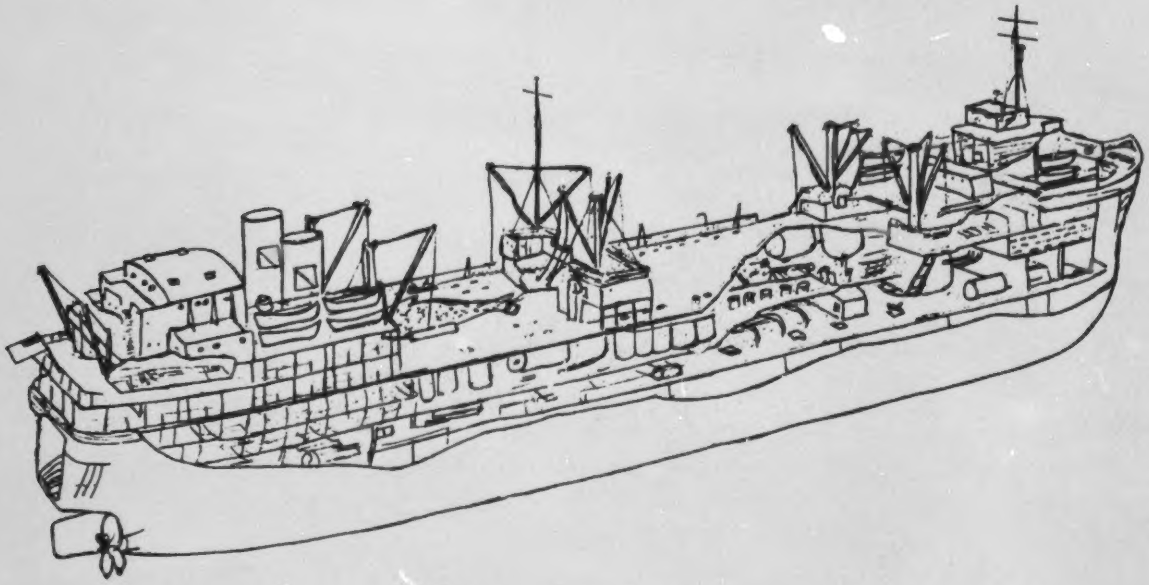
KRILL

24. It takes about 10 pounds of krill to make one pound of whale. How many pounds of krill would it take to make a 150 ton blue whale? Please show your work. (Hint: one ton = 2,000 pounds)

The herds were so bountiful, whalers were wasteful. One out of every four whales killed floated away before they could be skinned. As in the early days of whaling off California, shore stations were built to process the whales. The whalers refused to learn any lessons from their experiences in the North Atlantic. They picked the slowest species in the Antarctic, the humpback whale, to hunt. And they hunted it with no mercy. In 1911 8,500 humpback whales were killed. By 1925, only 9 humpback whales could be found to kill.

25. Destroying your source of income does not seem to make much sense. How might the whalers have protected the whale population and still remained in business?

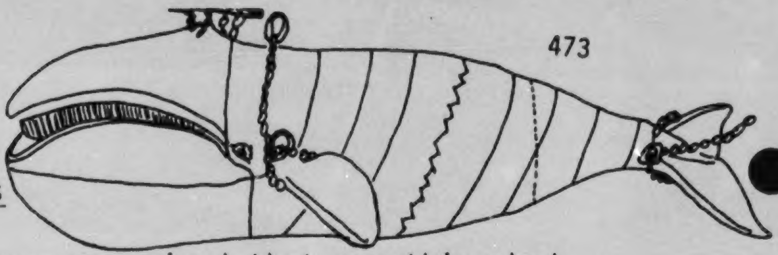
Norwegian whalers were soon joined by the British, French and Japanese. The whalers succeeded in killing off the whales that bred near the shore stations. This "success" forced the whalers to go out to sea to find whales. Hauling the dead whales back to the shore stations was expensive. In the spirit of Svend Foyn, another Norwegian captain solved this problem. He constructed a large "factory" ship that could accompany the fleet out into the Antarctic ocean. The ship had a slipway by which the whale was hauled onto the deck to be processed. The idea was a success. Within five years, thirty-eight factory ships were operating. Whaling catches increased from 10,500 per year to 40,200.



Factory Ship

26. What is a "factory ship"?

Gone were the days of the personal challenge to nature's largest animals. In its place was a large, well-knit unit that used speed and explosives to kill the whale. The extinction of all whales was now possible.



Regulating Whaling Nations

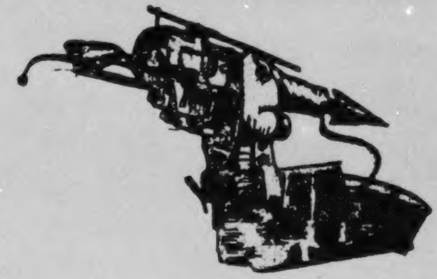
In 1931, whaling nations recognized that something had to be done. The International Convention for the Regulation of Whales met in Geneva, Switzerland. The Convention agreed to protect right whales and bowhead whales, immature whales, and females accompanied by a calf. Unfortunately, the Convention had no "police powers" to enforce the agreement. The slaughter of whales continued.

27. What is meant by the term "police powers"?

Many marine scientists predicted that the whale would become extinct if the slaughter continued. Following World War II a second attempt was made to establish whaling controls. The International Whaling Commission was created. Most of the world's whaling nations joined the Commission. The Commission had the duty to set minimum-length requirements, the opening and closing dates for the whaling season, and an annual Antarctic quota. Since 1949 the IWC has held yearly meetings.

28. What is the IWC?

Despite its impressive responsibilities the Commision was also doomed to the role of a powerless administrator. Any member nation, if it gave 90 days notice, could refuse to obey any Commission decision. Also the Commission was powerless to limit the number of factory ships or to allocate a quota to any of them.



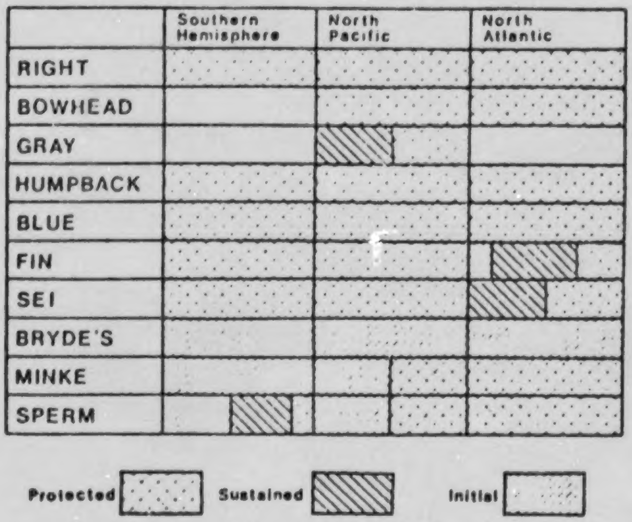
Harpoon Gun

In the years since the creation of the International Whaling Commission, the number of whales has continued to decrease. Often the necessity to make decisions based on the opinions of the member nations has resulted in protection for the various species of whales coming too little and too late. For example, scientists and annual catch statistics predicted that the blue whale was being hunted into extinction, In spite of these predictions, the Japanese, Russian, and Dutch members refused to agree to protect the blue whale. In 1964 the number of blue whales killed dropped to 20 for the entire whaling industry. Compare this number with the 29,400 killed in 1931.

29. Do you think the blue whale is still an important commercial (money making) whale? Please explain your answer.

Following the 1964 season the member nations agreed to place the blue whale on the protected species list. In effect the whaling industry had waited until the blue whale could no longer be hunted profitably before they would protect it!

Since the middle 1970's, the International Whaling Commission has strengthened its controls. Armed with scientific knowledge, the Commission has succeeded in protecting many hunted whales species. For other species, maximum quotas are established. Whaling nations seem to be more willing to follow the Commission regulations. These events are hopeful signs for the whale.



30. The chart above shows the whale species protected by IWC regulations. Whales labeled "Sustained" may be hunted at the same numbers hunted in previous years.

Whales labeled "Initial" may be hunted at higher levels than previous years. List the whale species which may be hunted at higher levels.

a.

b.

c.

Many people feel that the IWC cannot save the whales alone. These people feel that whaling nations, particularly Japan and Russia, will continue to whale as long as it is profitable. They will hunt the whales to extinction. As a result of these feelings, groups have been organized. These groups place political and economic pressures on whaling countries. Many conservation organizations have suggested that Americans do not purchase any Soviet or Japanese products.

31. a. What are three products the United States imports from Japan or the Soviet Union?

I.

II.

III.

b. Do you own any of the products you listed?

c. How might not buying Japanese or Soviet products stop these nations from whaling?

Today the only part of a whale with no real value is the baleen (whalebone). Once the most prized part of a whale, baleen is now considered worthless and most is discarded. The balance of the animal, however, is utilized to the last scrap.

The blubber is peeled from the carcass in great blankets. It is finely chopped and cooked in large steam boilers. The oil is drawn off and placed in tanks. Later it is transferred into small tankers. The tankers carry the oil to ports in various countries where it is further processed. The processed oil is used in foods, detergents, shoe polish, and special lubricants.

Once stripped of the meat, the bones are sawed into small pieces. The pieces are pressure-cooked to remove the large amounts of oil contained in the porous bones. The residue is ground and dried for bone meal. The teeth of the sperm whale are still saved for use in the making of carved souvenirs (Scrimshaw).

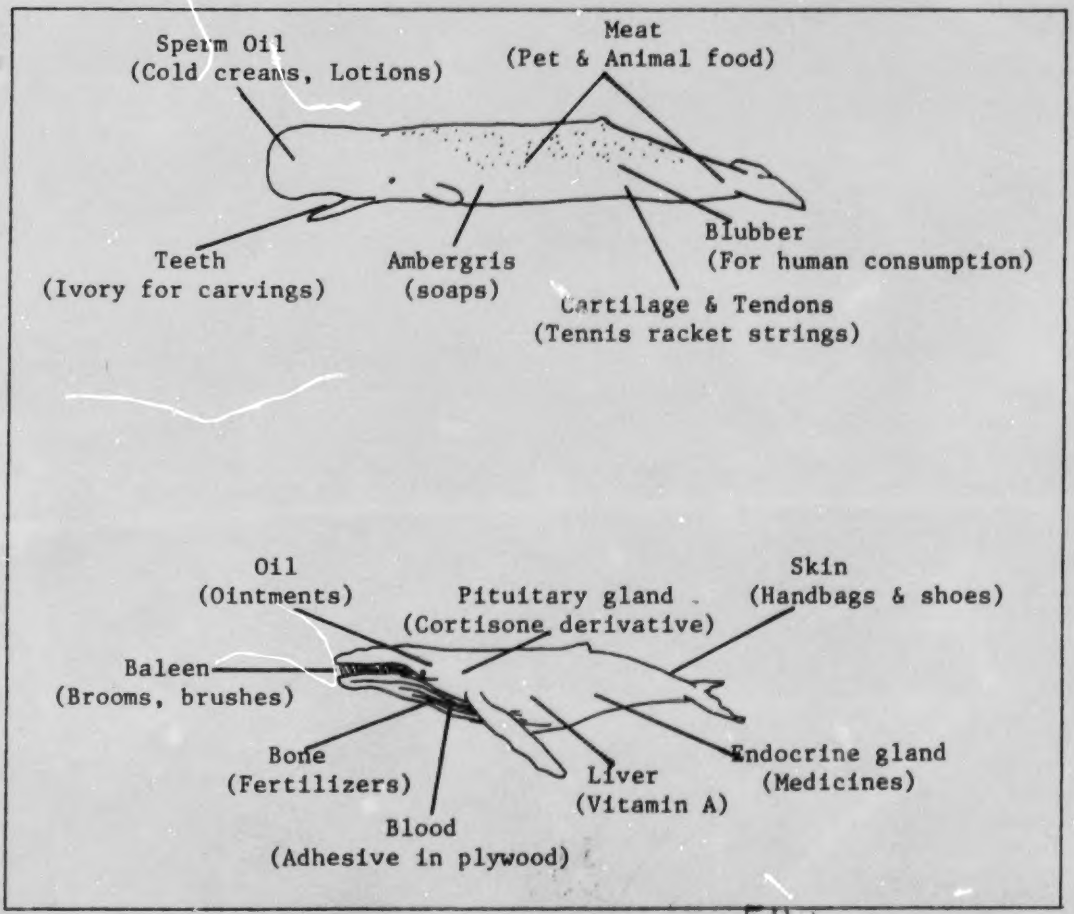
32. In the days of sailing ships, whale oil was used in lamps. How is whale oil used today?

The meat fillets are treated in different ways depending on the type of whale. The meat of the sperm whale is not considered edible. It is cooked to remove the oil. The remainder is dried and ground up for livestock feed. The choice pieces of the rorqual whales, especially the small younger ones, are carefully cut into manageable pieces. The pieces are frozen, and shipped to Japan. Some of it is eaten raw with a soy-horseradish sauce. Much of the balance is incorporated into a widely sold fishmeat sausage. Whale meat which is processed for sale in Europe is cooked and canned. A widely used meat extract is made from whale juices.

The juices are pressed from the steamed meat during removal of the oil. The extract is shipped to European markets.

The meat scraps and internal organs, plus flukes and flippers, are cooked for their oil content. The residue is dried, and ground for livestock feed. Thus, the largest living creatures the world has ever known are leaving their sea in tanks, cans, and sacks. They are leaving at a rate too rapid for their survival.

33. Where are most whale products sold?

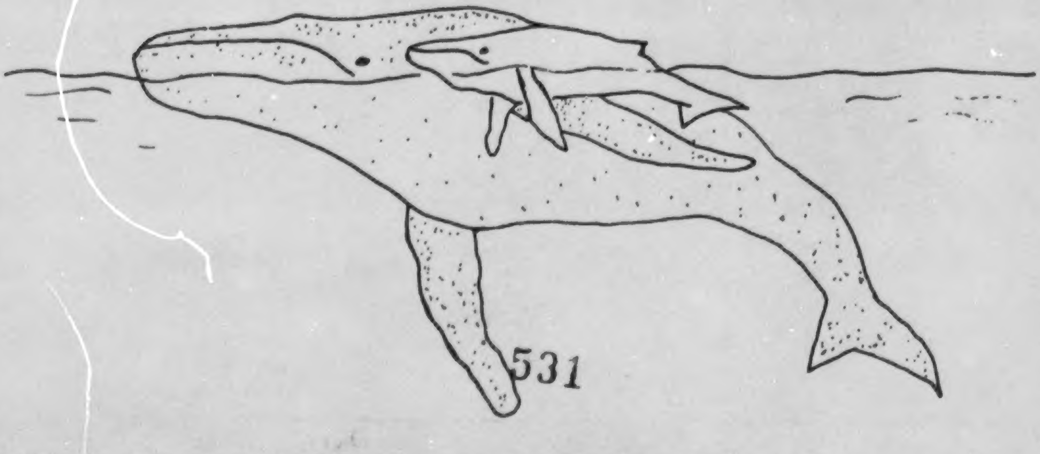

Sperm Oil
(Cold creams, Lotions)
Meat
(Pet & Animal food)
Teeth
(Ivory for carvings)
Ambergris
(soaps)
Blubber
(For human consumption)
Cartilage & Tendons
(Tennis racket strings)
Oil
(Ointments)
Pituitary gland
(Cortisone derivative)
Skin
(Handbags & shoes)
Baleen
(Brooms, brushes)
Bone
(Fertilizers)
Blood
(Adhesive in plywood)
Liver
(Vitamin A)
Endocrine gland
(Medicines)

34. All / None of the products listed can be derived from sources other than whales. (Circle the correct answer).

Fears for the preservation of whales have been expressed over the last hundred or more years. In spite of these concerns, little has been done. The whale population has had no escape from the whale hunters during this century.

The question of the future of some races of whales may have already been settled, These whales are already at such a low number that our lifetimes will not see their recovery. Others are not yet in these dire straits. They may return in sufficient numbers someday to be harvested under controlled conditions. If this recovery is to happen, action must be taken now to effectively protect these whales. It is up to us.

35. It has been said that whales are an indicator of the health of the world's living systems. What do you think is meant by this statement?



Indian Whalers - Find That Word

D U G O N G C E R E M O N Y E S
G U N W A L E S E W B I L L S A
U S G B A R B A R A L E F T T V
N H C O N B A R B S O T H E E E
N I B L U B B A R S W A I A E D
E D I L S T A R B O A R D M R W
Y E B O W E C A R C A S S A S H
C S T E E R S A N D U G Y B M A
R I T U A L S C N O E N E O A L
C A B L U B B E R O A S A A N E
P O R T S I D E B L E W T T O S

Directions:

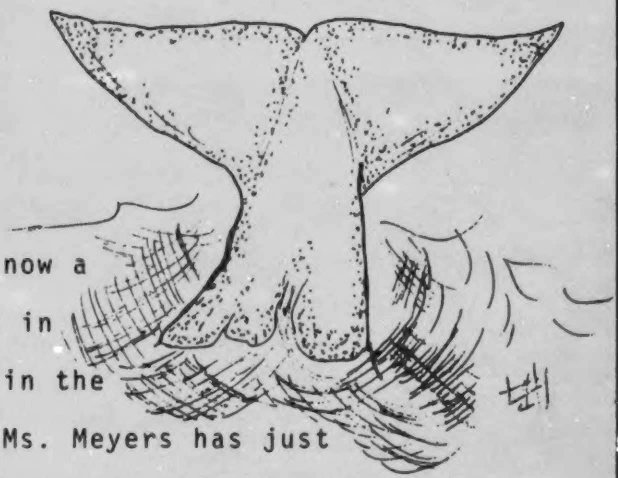
The word search above contains a number of words related to native whaling. It also contains other unrelated words. Find and circle ONLY those words which answer the clues given below. It may help you to first write the word in the blanks provided. Then search the above maze of letters for the word you have written. The words may be written horizontally, vertically, or diagonally.

Clues:

1. Northwest coast native whalers used this special boat (2 words). _ _ _ _ _ _   _ _ _ _ _
2. After a successful hunt, the native whalers towed this back to camp. _ _ _ _ _ _ _
3. The upper sides of a boat or ship. _ _ _ _ _ _ _ _
4. Native whalers placed their ropes on this side of the boat (the right side when facing forward).

   _ _ _ _ _ _ _ _ _
5. The choice pieces of this were given to important people in the tribe. _ _ _ _ _ _ _

6. These were inflated, blown up to make the line float. _ _ _ _ _
7. Part of this special event included placing eagle down on the whale. _ _ _ _ _ _ _ _ _ _
8. This rope was attached to the harpoon head. _ _ _ _ _ _ _ _ _
9. This person turned the boat away from the whale's giant tail. _ _ _ _ _ _ _ _ _ _ _ _ _
10. These were performed to gain the favor of the whale spirits. _ _ _ _ _ _ _ _
11. These were made of antlers and kept the harpoon from pulling out. _ _ _ _ _ _
12. The captain stood in this part of the boat. _ _ _
13. This is seen when a whale exhales. _ _ _ _ _



Sailing Whalers - Save My Story!

The last sailing whaling ship is now a floating museum at the Mystic Seaport in Connecticut. Judith A. Meyers works in the Education Department at the museum. Ms. Meyers has just finished the final draft of her book Waldo the Whale. As she walks along the shore, she reads the draft. "Oh! No!" Can it be? Ms. Meyers has stepped in a hole left by a discourteous clam digger. Up in the air goes Waldo the Whale. Down on the sand land the pages, out of order.

What can you do? On the next page, Ms. Meyers has arranged the pages. The pages on the left are the text. The pages on the right are the illustrations. Ms. Meyers has numbered the text pages and lettered the illustrations.

A. The text page numbers are given below. In the blank next to the number, write in the letter of the illustration that goes with the text page.

Text Page	Illustration
1.	______
2.	______
3.	______
4.	______
5.	______

TEXT

1.

On the *Morgan*'s deck stood heavy brick fireplaces called tryworks.
There huge iron try-pots bubbled with chunks of blubber
melting the blubber into oil.
After the oil was cool, Patrick helped ladle it into large barrels.
Then the barrels were stored down below in the hold of the ship.

2.

Waldo swam faster and faster, pulling men
and boat behind him. It was a furious "Nantucket sleighride!"
Soon all his energy was gone. He was being jabbed
by a long pole with a sharp head on it, called a lance.
He could fight no longer.
Patrick Biggins was in that whaleboat.
He had thought that catching his first whale would be fun.
Instead, he felt very sad
as he watched that great and noble mammal
roll over on his side and die.

3.

Waldo saw one of the whaleboats come straight at him.
He was curious.
He wanted to know what all the excitement was about.
When the whaleboat came too close, Waldo turned in fright.
Too late! Waldo felt a stinging pain in his side.
He tried to swim away fast. Something was slowing him down.
The sting in his side was attached to a rope
that was attached to the whaleboat
and he was dragging it all behind him...
he had been harpooned!

4.

He was still sad as the men went on with their work.
They hoisted the whale's body to the side of the *Charles W. Morgan*.
Then they cut big chunks of fat,
called blubber, from the whale's carcass.

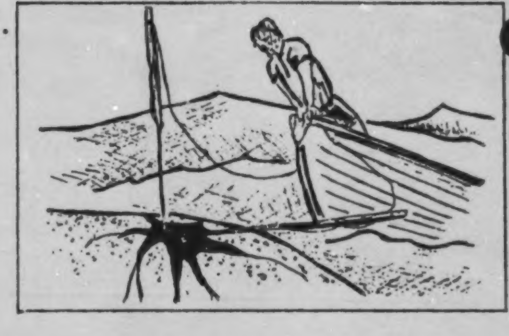
5.

At the very same moment Waldo spotted
C-H-A-R-L-E-S--W.--M-O-R-G-A-N,
Patrick Biggins, the lookout in the masthead, spotted Waldo
and sang out "thar she blows!"

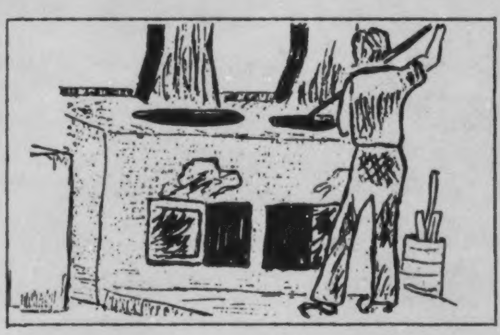
Patrick had run away from his family's farm last June, and
traveled to New Bedford with dreams of adventure.
He signed on the whaleship *Charles W. Morgan* for a
voyage that might last up to five whole years!

ILLUSTRATIONS

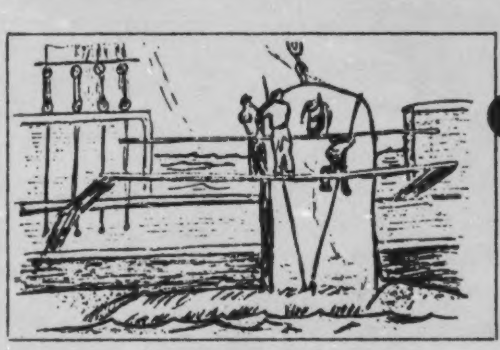
A.



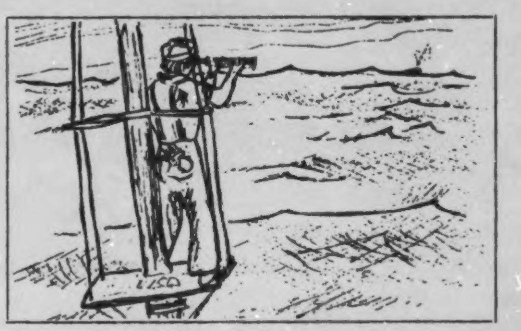
B.



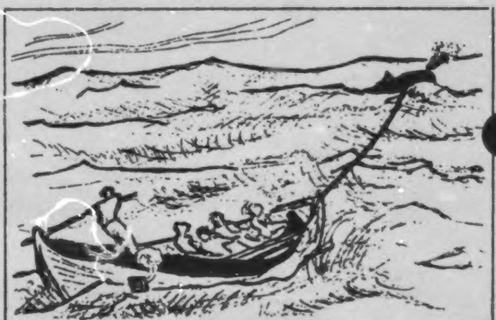
C.



D.



E.

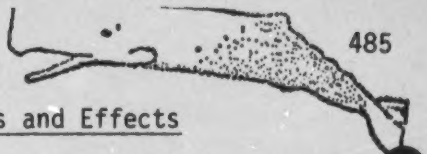


B. You've already been a big help. You've matched the words and the pictures. Now you can put the pictures in the correct order. The pictures represent a time sequence. The letters of the illustration are given below. In the blank next to the letter, write the order in which the pictures occur. For example, next to the picture you think happens first, you should write "first". Continue until you have placed all five pictures in their proper order.

Illustration	Order
A.	_____
B.	_____
C.	_____
D.	_____
E.	_____

C. The pages with the ending to the story are missing! In the space below finish the story of Waldo the Whale. Use the pages on the right for your illustrations and the pages on the left for your text. If you need more pages, use plain paper.

TEXT	ILLUSTRATIONS



Modern Whaling/Regulating Whaling Nations - Causes and Effects

The Times headline read "BRIDGE FALLS AFTER RAMMING BY FREIGHTER!" This statement gives us a lot of information. It tells us what happened (the bridge fell). It also tells us what caused the event (ramming by a freighter). The headline is an example of a cause and effect statement. The cause was the ramming by a freighter. The effect was the falling of the bridge. The effect is what happens because of the cause.

Below you will see two lists. The list on the left shows some causes related to whaling. The list on the right shows some effects resulting from the causes. Connect the effect with its cause by writing the letter of the effect in the blank in front of the cause. The first one is done for you.

Causes	Effects
C 1. Pennsylvania oil wells produced kerosene.	A. The International Whaling Commission was created.
__ 2. Svend Foyn built the first steam powered whaler.	B. By 1925, only 9 humpback whales could be found to kill.
__ 3. Svend Foyn pumped compressed air into dead whales.	C. Whale oil was replaced as a fuel for lamps.
__ 4. Svend Foyn's whaling techniques were very successful.	D. The rorqual whales which sink after death could be hunted.
__ 5. Krill reproduce explosively.	E. Many whales face extinction.
__ 6. Whalers in the Antarctic picked the humpback whale.	F. The fast swimming rorqual whales could be chased
__ 7. Whalers killed all of the whales that bred near Antarctic shore stations.	G. Groups have placed economic and political pressure on whaling countries.
__ 8. Marine scientists predicted that the whale would soon become extinct.	H. Protection for the various species of whales has come too little and too late.
__ 9. IWC decisions are based on the opinions of the member nations.	I. By 1903, the blue whale was no longer found in the Northern Hemisphere.
__10. Many people feel that the IWC alone cannot save the whales.	J. Factory ships were developed to accompany the fleet into the Antarctic ocean.
__11. Whales are leaving the sea in tanks, cans and sacks.	K. Whales that fed on krill were very numerous.

TEACHER BACKGROUND - Holding On

Surrounded by the wonders of technology as we are, it is difficult to comprehend what hunting the whale was like for native Americans. "Holding On" gives your students an opportunity to examine one small facet of the complex business of native whaling. That facet is rope making. The lines used to secure the harpooned whale and the boat had to be strong. A broken line usually meant a lost whale.

"Part I - The Anatomy of a Rope" gives your students a chance to examine a modern rope. Since few of us have examined a modern rope, the following background is provided.

A rope is composed of three *strands* twisted together usually in a right-hand spiral. Occasionally a left-hand *lay* is used, but this is not common. The direction of lay is defined as being right-hand when the strands spiral away from you in a clockwise direction, and left-hand when they spiral in an anticlockwise direction.

Each strand is itself composed of *yarns* twisted together in the opposite direction to that of the rope's lay. That is to say they are laid up in a left-handed pattern in the strands of a right-hand laid rope.

Finally each of these yarns is made up of *fibers* twisted together in the opposite direction to the lay of the yarns in the strands, i.e. in the same direction as the lay of the rope. Thus it can be seen that the strands, yarns, and fibers are each laid up in a direction opposite to their internal composition. This is done to ensure that the rope binds snugly within itself and tends to stay laid up and not to unravel.

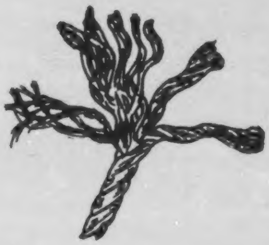


Figure 1 shows from (left to right) fibers, yarns, and two strands, making up a three-strand right-hand laid rope.

Parts II and III of "Holding On" provide opportunities for constructing ropes. These activities require natural fibers, preferably cedar bark and cedar limbs. It is possible to substitute other locally available fibers. In areas with native cedar trees grow, recently logged areas provide an abundant supply of cedar bark. Caution your students not to strip the bark from living trees. Best results will be obtained if you have an opportunity to practice these techniques prior to introducing them to your students.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished in pairs or small groups. If only a small supply of natural fibers is available, you may wish to have groups perform Parts II and III as a class demonstration. Upon completion of the activity, allow time for a discussion of the results.

KEY

Part I - Anatomy of a Rope

1. The observations recorded on the "Rope Chart" depend upon the particular rope sample in question.
2. a., b., c. Answers depend upon the experimental data.
   d. The answer depends upon the experimental observations. In general, the relationship between fiber thickness and strength is that the thicker the fiber, the greater the strength.
4. a. Your students should find that it is more difficult to pull the twisted fibers than the untwisted ones.
   b. The effect of twisting observed to this point is that twisting makes it more difficult to pull individual strands from the rope.
   c. The increased contact of surface area provided by twisting increases the frictional resistance to sliding making it more difficult to pull single strands from the rope.
   d. More twisting increases the difficulty with which single strands may be removed.
5. The volume of water recorded depends upon the experimental results.
6. a. Twisting increases the total strength of the five fibers.
   b. While answers will vary, a strong rope could be made from twisting together many small fibers. A yet stronger rope could be made by twisting these twisted "yarns" into strands. The twisted strands could then be twisted into a finished, strong rope.

Part II - Making Cedar Bark Lines

4. a. The Indian rope and the modern rope are alike in that they are made from a group of small fibers twisted together.
   b. While the Indian rope and the modern rope are both made from small fibers twisted together, they differ in the pattern of twisting. The fibers in the modern rope are twisted into yarns which are then twisted into strands and finally again twisted into the complete rope. The Indian rope would be equivalent to a large yarn.
   c. This question is provided to stimulate discussion. Modern rope may be considered "better" if strength per cross section is the criterion. Indian rope may be considered "better" if ease of construction by hand is the criterion. The important thing to stress is that each type of rope fulfilled a particular function and was, (or is) indeed, the "best" option available.

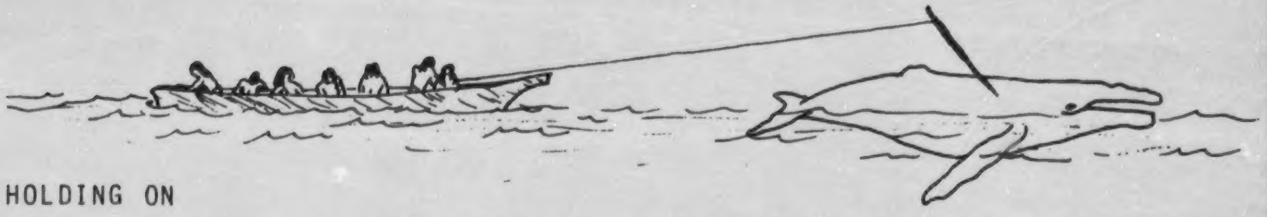
Part III - Cedar Branch Lines

4. a.—c. The questions and answers are the same as those found in Part II.

KEY WORDS

bark
branch
cedar
fiber
graduated cylinder
grain
harpoon
horizontal
limb
line
pliable
qualities
rope
sinew
strands
stripped
tendon
tradition
twist
yarn

* This activity is adapted from activities originally appearing in "Early Fishing People of Puget Sound" an Activity Packet from the ORCA Marine Education Project of the Pacific Science Center in Seattle, Washington.



HOLDING ON

For the North Coast Indians, hunting whales was a complicated business. Tradition and experience determined how everything was done. The canoes were built to speed through rough water. The harpoon was made to pierce the flesh and to stay in place. The lines were made to withstand the fury of an injured whale. How were these ropes made? What kinds of experiences led to rope design? In the following activity you will have an opportunity to learn a little about ropes. You will also have a chance to make the type of line used to hunt the gray and humpback whales.

Materials:

Assorted kinds and sizes of rope cut in two foot lengths (at least one rope per two students)

Scissors or knives to cut ropes

Buckets (one for each two students)

Water (used as weights)

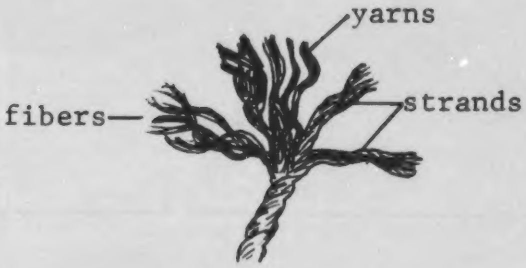
Graduated cylinder or measuring cup

The innermost layer of the two layers of the cedar bark

Cedar limbs (up to ½" diameter)

PART I - Anatomy of a Rope

Ropes are more complicated than they first appear. For example, many ropes are made of three strands. Each strand is made up of four yarns. Each yarn is made up of a great many fibers.



Procedure:

1. Obtain a two foot section of rope. Carefully untwist a few inches of the rope. Examine the rope end-on, and record what you see on the chart:

ROPE CHART

My rope is 2 feet long and ________ inches in diameter.
Number of strands =
Strand twist direction = Clockwise or Counterclockwise (Circle correct term)
Number of yarns per strand =
Yarn twist direction = Clockwise or Counter closkwise (Circle correct term)
Number of yarns in whole rope =
Number of fibers per yarn (count exact number) =
Number of fibers per strand (estimate) =
Fiber twist direction = Clockwise or Counterclockwise (Circle correct term)

2. Separate all the fibers from 1 or 2 yarns into 3 or 4 piles according to their length.
   a. What do you observe about fiber length?

   b. What do you observe about the thickness of fibers?

   c. Can you split a fiber into two or more fibers?

   d. Test some single fibers for strength. What is the relationship between fiber thickness and strength?

3. Take 1 yarn and loosen all the fibers. Untwist them and spread them back two or three inches apart. Put the fibers back together without twisting. Pull out 1/3 of the fibers.
4. Put the fibers together again and twist them 5 to 10 times. Now pull out 1/3 of the fibers.
   a. How is this different from pulling the untwisted fibers.

   b. What effect does twisting have?

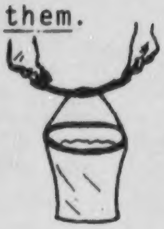
c. Why do you think this is so?

d. What happens when you twist even more?

5. Bunch five long fibers together. Don't twist them.

   Lift a bucket or can as shown.

   Add water to the bucket until the fibers break. Record the volume of water which the fibers broke. ________ml of water.



6. After the five fibers break, twist the five long pieces together quite tightly and repeat the experiment. Record the volume of water at which the fibers broke.

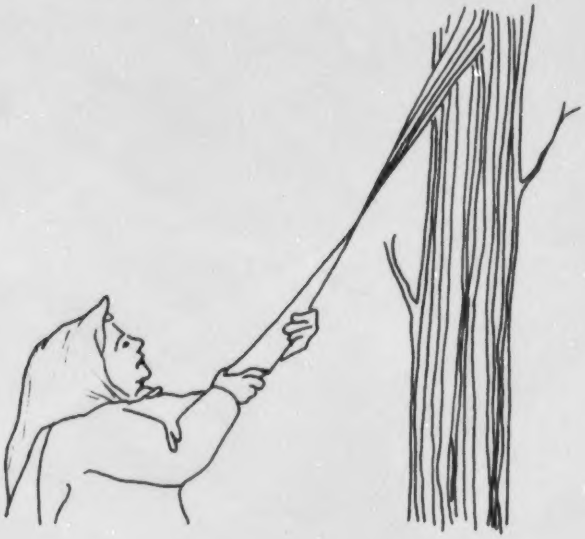
   ________ ml of water.

   a. Does twisting have any effect on the total strength of the five fibers?

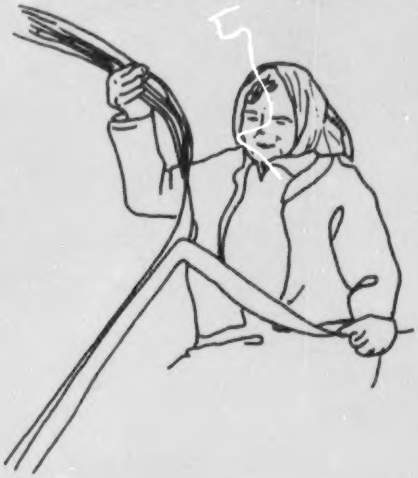
   b. As a North Coast Indian you have a supply of fibers. How would you make a strong rope?

PART II - Making Cedar Bark Lines

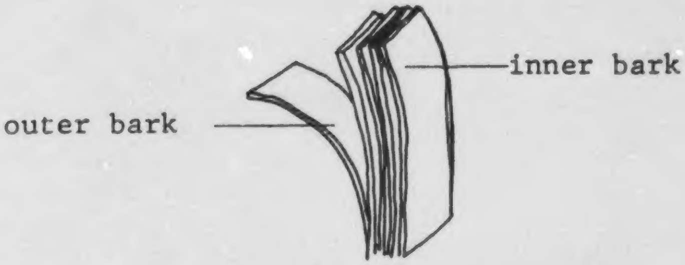
North coast Indians used cedar bark lines to secure the whales they harpooned. One of the qualities which makes bark so useful is its straight grain. This allows cedar to be easily split or stripped. To obtain fibers, bark was stripped from the tree by making a shallow horizontal cut in the trunk. Long strips were pulled off using alternate hands (figure A). The bark has two layers. The two layers were separated and the soft inner layer used for fibers (figure B). The inner layer is thick enough to be separated into several layers (figure C).



(A)



(B)



(C)

Procedure:

1. Obtain a bark strip about 2 feet long. Separate the layers of bark keeping a strip of inner bark about 2 feet long.
2. Split the inner bark into thin strips about ½ inch wide. Soak the strips in water to make them pliable.
3. Twist three of these thin lines into a strong rope.
4. Compare the Indian rope to the modern rope you examined in Part I.
    a. How are they alike?

    b. How are they different?

    c. Is one method of rope making better than the other? Why or why not?

PART III - Cedar Branch lines

North Coast Indians used several types of lines to secure their whales. The line attached to the harpoon head was made from fibers from whale tendons (sinew). This sinew line was attached to a line made from cedar limbs. You can make your own cedar branch lines using the following procedure.

Prodecure:

1. Obtain three or four cedar limbs. Strip the limbs of leaves.
2. Soak the limbs in water for 24 hours or longer.
3. Twist the limbs into a rope. These ropes have remarkable strength.
4. Compare the Indian rope to the modern rope you examined in Part I.
    a. How are they alike?

    b. How are they different?

    c. Is one method of rope making better than the other? Why or why not?

TEACHER BACKGROUND - Canoe Building

The dugout canoe well reflects the woodworking skills of the Indians of the North Pacific Coast. The brief introduction to North Coast Indian cultures provided in "Indian Whaling" oftentimes generates a deeper interest in these cultures. The following directions provide you with an opportunity to extend your activities dealing with native cultures. The instructions reflect the techniques used by North Coast Indians in constructing their canoes. Adapt the authentic Indian methods and materials to those you have available while maintaining touch with the procedures used by the native Americans.

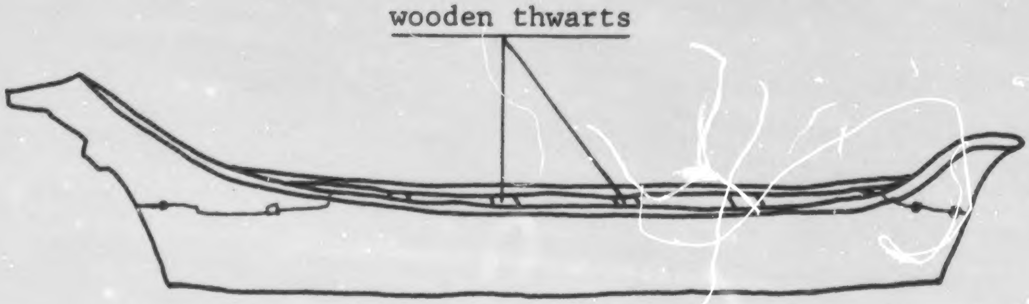
Materials:

Half a red cedar log of length up to 60'
Adze
Chisel
Stone
Maul
Needle
Cedar withes (tough, flexible twigs)

Procedure:

1. Shape outside of hull as desired with adzes and chisels.
2. Hollow inside by carefully splitting, chopping, and controlled use of fire if necessary, to give a graceful and seaworthy form.
3. To widen sides, put water in canoe (depth of a few inches) and red hot stones. (Stones are heated in a fire, then placed in water to make it boil). Build a slow fire under the sides of the canoe. This steaming makes the canoe spread apart easily and flattens the bottom. Wood thwarts are used to spread the sides apart to final shape and then permanent thwarts are attached. Use care not to let canoe crack from heat. The thickness of hull can be controlled with plugs. Drill hole and insert a wooden plug the length of the hole's depth. When inner surface of hull shaping reaches plug, the proper thickness has been reached.

4. Bow and stern pieces were fitted and sewn to hull with cedar withes. If a canoe cracked during construction, the crack was patched with pitch applied with hot rocks handled with tongs.



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* This activity originally appeared in "Early Fishing Peoples of Puget Sound" an Activity Packet from the ORCA Marine Education Project of the Pacific Science Center in Seattle, Washington.

TEACHER BACKGROUND - Scrimshaw

Whales and whaling cannot help but conjure up images of sailing ships and days gone by. As we have seen, the days are, unfortunately, not entirely gone. "Scrimshaw" serves to introduce your students to a truly American folk art form. The years long voyages provided sailors with ample opportunity to engage in hobbies. The range in artistic ability found in scrimshaw pieces runs from exquisite to primitive. On many whalers everyone from the captain to the lowest crewman would have a piece of scrimshaw in progress. The favored pieces to carve were teeth and baleen or "whale bone". The baleen became elaborate corset stays, while the teeth sometimes retained their shape and other times became pastry wheels or other domestic articles. The artform was so absorbing that lookouts would oftimes not report the sighting of a whale so as not to disturb their carving. In place of whale teeth and baleen, this activity uses "modern whalebone". The activity is enjoyable and clearly reveals the patience possessed by the seamen.

Modern whalebone may be found in abundance. It is the smooth plastic found in many disposable containers. Yogurt containers work particularly well. Bleach bottles and similar containers also work well. The containers should be cut into manageable size pieces (1½" X 3" or 4") before class. Cup size yogurt container lids work very well and may be made into an attractive mobile upon completion of the activity. Your students can often supply the containers although it is recommended that you do not tell them what the containers are for until you introduce the activity.

While plastic containers seem to be the most manageable material for students, other mock whalebones are available. Ivory soap may be easily carved or inscribed. Incised lines may be filled in with permanent felt markers and the excess pigment may be carefully wiped off with a damp (not wet) paper towel. The final step is a polishing with a soft cloth.

Plaster of Paris also provides a substitute. Prepare plaster of Paris "teeth" by mixing the plaster with water. Drop small spoonsfull on wax paper. When sufficiently hardened, remove from paper. These "teeth" will be fairly round. Your students may use nails to sketch their designs. If a pendant is desired, carefully make a small hole at top with a nail. Use a fine brush and black tempera paint to paint over lines of design. Rub firmly but carefully over entire piece to smear paint. String yarn through hole for hanging. You may experiment with other pigments. A word of caution: the plaster is porous and tends to absorb felt pen and similar coloring agents. A gentle scraping with a dull knife can remove most of the absorbed pigment. Unfortunately, it can also remove much of the drawing. To minimize frustration, should you elect this method, practice the technique yourself before having your students perform the activity.

The above materials are soft in comparison with whale teeth and baleen. Your students can obtain a more realistic idea of the difficulties involved in scrimshaw by using the inside of hard shell clams or the outside of beef bones. In the event you have students who express an interest in "advanced scrimshaw", the technique for preparation and use of beef bones is provided below.

Soup bones provide the raw material for this advanced activity. Most butchers are willing to cut soup bones into 2½ inch lengths for you if you explain how you are going to use them. If your butcher is very friendly, she may cut the lengths in half lengthwise so that the pieces more nearly resemble whale teeth.

There are two ways to prepare the beef bones:

1. Boil bones for 2½ to 3 hours to remove meat and gristle. (Make soup with the broth!) Scrub bones and remove all excess meat and debris. Reboil the bones for half an hour in a strong detergent solution to remove the grease. Pat bones dry and leave to dry for 3 to 4 days. You may wish to put them in the oven on racks for a few hours for drying.
2. Boil bones for 2½ to 3 hours to remove meat and gristle. (Make soup with the broth!) Scrub bones and remove all excess meat and debris. Reboil the bones for half an hour in a strong detergent solution to remove the grease. Soak in sodium hydroxide for 5 days to 2 weeks to remove excess meat, gristle and marrow. Pat dry and leave to dry for a day.

Provide sufficient sandpaper for your students to smooth the bone surfaces. One four-inch square of coarse and two four-inch squares of finer grit papers are required for each student. The choice of carving tools is limited only by your imagination. The traditional tool was the ubiquitous sailor's pocket knife. The highlighting materials used by whalers ranged from soot from the fires used to render or "try" the oil from the blubber, to paint, to tar and India ink. Most often the pigments were black, but red, green and blue highlighting is also seen on some pieces. A variety of pigments may be used by your students. Lampblack may be found in some old, well-stocked hardware stores. Charcoal, pastels and crayons also work well. Felt tip pens tend to penetrate the bone and as a result do not work well. Let your students be as creative in their pigment choice as the original artisans. Disasters may be sanded away with a little effort!

Duplicate the activity pages. One set is recommended per student. Caution your students about the use of sharp carving tools and circulate through the room as the activity is performed to minimize the likelihood of accident. Plan to display the finished pieces (perhaps in the library or some other central location). You may provide extra "whale bone" or bones for interested students to take home and carve. Provide resources and the incentive to follow up on the scrimshaw with reading and projects dealing with early whaling. This activity provides an excellent opportunity for favorable "P.R." for your program and for the school. Make the most of the opportunity.

KEY WORDS

baleen
carving
crevices
cruises
lampblack
pigment
scene
scrimshander
scrimshaw
whalebone
whaler

SCRIMSHAW

Sailors aboard the sailing whalerships were gone from home for long periods. Cruises of two, three or four years were not uncommon. Sailing was hard work in bad weather and there was very little free time. In fine weather, the crew of a sailing whaler had enough spare time to engage in hobbies. Whalemen passed the time of day carving designs or scratching pictures into whale teeth or into "whalebone", the baleen of the non-toothed whales. This carving or scratching is known as scrimshaw. Sailors sketched sea scenes, initials, designs, their ship and the catch and other scenes from life at sea. Form these works of art we have a good idea of those things about which a sailor thought. We also have an idea of those things which he appreciated most during his years at sea. Whales are now protected by United States law. New whalebone and whale products are not permitted into the country. In the following activity you will use "modern whalebone" to try your patience as a "scrimshander".

Materials:

Modern whalebone

Nails, compass, single edged razor blades or any type of carving tools

Crayons, lamp black or charcoal, pastel chalks

Pencil

Paper towel

Soft cloth

Procedure:

1. Draw a design lightly on the "whale bone". The first time, keep it simple. It does not have to deal with whaling.
2. Carve out design with nail or other carving tool.
3. Fill in design with lamp black or other pigment. (Caution: A little lamp black goes a very long way.) Be sure to fill in all the crevices.
4. Use a paper towel to wipe off the surface of your "whale bone". The black should wipe off the unscratched surface of the "whalebone" leaving only the lines colored.
5. If the design needs more carving, do it and refill.
6. Polish the bone with a soft cloth for the final gleam.
7. Display your scrimshaw work of art.

TEACHER BACKGROUND - Blood Money

With the passage of time, things such as whaling voyages become blurred. It is hard to realize that these adventures were business endeavors that cost money and that made or lost money. "Blood Money" provides your students with some actual cost figures for the outfitting and purchase of a whaling ship and also some figures related to wages and compensation. The figures are interesting, at the onset, because of the price increases we see in commodities we recognize (remember the 'good old days' of paying 3.5 cents a pound for rice?). The lists of articles are interesting because of what they tell us about life on a sailing whaler. The questions included with the text information are designed to help your students uncover the story behind these lists and figures. This activity provides your students with an opportunity to exercise their critical reading skills. Since many students are unfamiliar with current prices, you may wish to post current newspaper advertisements or similar sources of price information.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished by individual students as a homework assignment or as an in-class assignment. "Blood Money" profits from a post-activity discussion in which you paint a picture of life on an American sailing whaler by drawing together the answers provided by your students.

KEY

The answers are found in italics on the accompanying copies of the student text pages.

KEY WORDS

balanced diets
canvas
cask
cereals
cordage
cruise
deductions
discount
duck
earn
gross
investments
listing
nutritionists
outfit
percent
principal
product
profit
salaries
seaman
sheathing
stocked
try pots
variety
vessel
wages

BLOOD MONEY

Part I

TYPICAL COST OF WHALING VOYAGE

Below is a list of the principal articles required to outfit a vessel for a sperm whaling voyage. The amount of each article and the cost at the prices which prevailed on January 1, 1844 are also shown. Use this information to answer the questions.

ARTICLE	AMOUNT	PRICE	COST
Oil Casks	2,000 Bbls.	$ 1.25	$ 3,500.00
Beef & Pork	240 Bbls.	8.50	2,040.00
Flour	220 Bbls.	5.25	1,155.00
Corn	75 Bushels	.55	41.25
Beans & Peas	14 Bushels	1.25	17.50
Corn Meal	5 Bbls.	3.50	17.50
Rice	2,500 Lbs.	.11	275.00
Potatoes	1,200 Lbs.	.035	42.00
Cheese	150 Bushels	.35	52.50
Butter	800 Lbs.	.07	56.00
Dried Apples	900 Lbs.	.13	117.00
Vinegar	600 Lbs.	.04	24.00
Cod Fish	10 Bbls.	3.50	35.00
Molasses	800 Lbs.	.03	24.00
Tea, Black	1,600 Gals	.27	432.00
Tea, Hyson	250 Lbs.	.35	87.50
Raisins	20 Lbs.	.60	12.00
Sugar	200 Lbs.	.05	10.00
Coffee	1,000 Lbs.	.075	75.00
Tobacco	1,000 Lbs.	.08	80.00
Duck, Heavy	60 Pieces	18.00	1,080.00
Duck, Light	36 Pieces	8.00	288.00
Tar	20 Bbls.	2.25	45.00
Whale Boats	6 Boats	60.00	360.00
Oars	7 Sets	8.50	59.50
Boards	4,000 Feet	20.00	80.00
Nails, Composition	700 Lbs.	.22	154.00
Copper, Sheathing	8,500 Lbs.	.21	1,785.00
Cordage	8,500 Lbs.	.10	850.00
Tow Lines	3,000 Lbs.	.12	360.00
Try Pots	3 Pots	60.00	180.00
Cloth	6,000 Yards	.09	540.00
Iron, Whaling Crafts	4,000 Lbs.	.15	600.00
Clothing, Ready-Made			2,800.00
Labor in Port			2,500.00

TOTAL COST OF OUTFIT 19,774.75
COST OF A TYPICAL VESSEL . . 31,224.72

COMBINED COST OF VESSEL
AND OUTFIT . . . .$ 50,999.47

From: The American Whaleman by Elmo Paul Hohman

1. **What was the whale product sought by the whalers?**

The whalers sought whale oil derived from the blubber.

2. **How many different types of food were stocked on the ship?**

Twenty types of food were stocked (this includes two varieties of tea).

3. a. Nutritionists (people who study balanced diets) place food in five groups the groups are listed below. Place the foods taken on the whaling ship in their proper place.

MEATS (including beans, peas, peanut butter)	FRUITS & VEGETABLES	BREADS & CEREALS	MILK	EXTRA FOODS (soda pop, candy, etc.)
Beef	*Corn*	*Flour*	*Cheese*	*Vinegar*
Pork	*Dried Apples*	*Corn Meal*	*Butter*	*Molasses*
Beans	*Raisins*	*Rice*		*Tea, Black*
Peas		*Potatoes*		*Tea, Hyson*
Cod Fish				*Sugar*
				Coffee

b. Which group had the fewest foods? What is one possible reason for this group having so few listings?

The Milk group had the fewest listings, most probably because of the lack of refrigeration.

c. Do you think the sailors had a lot of variety in their meals? What foods not listed might they have been able to add to their diet?

Most students will say "no variety". They could have added fish to their diet. Also whale, although sperm whale meat is considered inedible because of its strong taste.

4. Duck is a fine, white canvas-like material. What are two possible uses for duck on a whaling ship?

a. *Sails*

b. *Clothing*

5. Copper sheathing is used to protect wood from attack by marine "worms." Where, do you suppose, the copper sheathing was "worn" by the ship?

It was "worn" on the bottom of the ship as copper plating.

6. What were the try pots?

The try pots were large pots used to render (boil out) oil from the blubber.

BLOOD MONEY

Part II

The costs shown in Part I had to be paid before the ship sailed. Other costs had to be paid when the trip was over. The wages for the captain and crew made up most of the after-cruise expenses. The following are the wages for one seaman's four year voyage in 1849.

Sailor's share in money		$262.25
Less:	Fitting, shipping, medicine chests	10.00
	10% discount on share	26.22
	3% insurance on share	7.86
	Money advanced for voyage	70.00
	Interest on same	16.80
	Cash advanced on voyage	30.00
	Interest on same @ 1%/month	7.20
	Clothing drawn	40.00
		$208.08
Amount paid at end of voyage		$ 54.17

1. This figure is called the gross wages. (The "before tax" figure).

   a. What did this sailor make (gross for each year of the four year cruise?

   The annual gross was $65.56.

   b. How much was this per day? (Hint: There are 365 days per year.)

   The daily gross was $.17 (yes, seventeen cents).

2. This figure and the "Clothing drawn" help pay back what the owner spent to outfit the ship. Who also collected the other "deductions" from the seaman's pay?

   The owner also collected the other "deductions". Pay levels for officers and men were little short of robbery.

3. a. How much cash did the ship's owner really have to pay this seaman?

   Upon completion of the voyage, the owner had to pay the seaman $54.17.

   b. The total cost for a seaman was the amount paid in cash at the end of the voyage plus fitting and clothing expenses. What was the total amount it cost the owner for 4 year's of this sailor's life?

   Four years of this sailor's life cost the owner $104.17.

4. a. From Part I, what was the total combined cost of vessel and outfit? *$50,999.47*.

   b. The whaleships brought in an average of $16,000 a year. What would be the value of the cargo for this four year cruise? *$64,000.00*.

   c. Total crew salaries amounted to $10,000. How many similar four year cruises would be required to pay for the entire ship, outfitting and salaries? ________________.

   One cruise would pay for the works (ie. 50,999.47 + 10,000 = $60,999.47 which is less than the $64,000 gross income.

5. Ship's owners took advantage of their crews. Owners made from 25 to 50 percent a year clear profit on their investments.

   a. At 50% profit, how many years would be required to pay off the investment?

   At 50%, two years would be required to pay off the investment.

   b. About what annual percentage did the owner described above in question 4 earn? *The owner earned about 25% per year (actually 26%/year).*

   (Hint: annual percentage = $\frac{\text{annual income to owner - total of sailors annual salaries X 100)}}{\text{total combined cost of vessel and outfit}}$

BLOOD MONEY

Part I

TYPICAL COST OF WHALING VOYAGE

Below is a list of the principal articles required to outfit a vessel for a sperm whaling voyage. The amount of each article and the cost at the prices which prevailed on January 1, 1844 are also shown. Use this information to answer the questions.

ARTICLE	AMOUNT	PRICE	COST
Oil Casks	2,000 Bbls.	$ 1.25	$ 3,500.00
Beef & Pork	240 Bbls.	8.50	2,040.00
Flour	220 Bbls.	5.25	1,155.00
Corn	75 Bushels	.55	41.25
Beans & Peas	14 Bushels	1.25	17.50
Corn Meal	5 Bbls.	3.50	17.50
Rice	2,500 Lbs.	.11	275.00
Potatoes	1,200 Lbs.	.035	42.00
Cheese	150 Bushels	.35	52.50
Butter	800 Lbs.	.07	56.00
Dried Apples	900 Lbs.	.13	117.00
Vinegar	600 Lbs.	.04	24.00
Cod Fish	10 Bbls.	3.50	35.00
Molasses	800 Lbs.	.03	24.00
Tea, Black	1,600 Gals	.27	432.00
Tea, Hyson	250 Lbs.	.35	87.50
Raisins	20 Lbs.	.60	12.00
Sugar	200 Lbs.	.05	10.00
Coffee	1,000 Lbs.	.075	75.00
Tobacco	1,000 Lbs.	.08	80.00
Duck, Heavy	60 Pieces	18.00	1,080.00
Duck, Light	36 Pieces	8.00	288.00
Tar	20 Bbls.	2.25	45.00
Whale Boats	6 Boats	60.00	360.00
Oars	7 Sets	8.50	59.50
Boards	4,000 Feet	20.00	80.00
Nails, Composition	700 Lbs.	.22	154.00
Copper, Sheathing	8,500 Lbs.	.21	1,785.00
Cordage	8,500 Lbs.	.10	850.00
Tow Lines	3,000 Lbs.	.12	360.00
Try Pots	3 Pots	60.00	180.00
Cloth	6,000 Yards	.09	540.00
Iron, Whaling Crafts	4,000 Lbs.	.15	600.00
Clothing, Ready-Made			2,800.00
Labor in Port			2,500.00
	TOTAL COST OF OUTFIT		19,774.75
	COST OF A TYPICAL VESSEL . .		31,224.72
	COMBINED COST OF VESSEL AND OUTFIT		$ 50,999.47

From: The American Whaleman by Elmo Paul Hohman

1. What was the whale product sought by the whalers?

2. How many different types of food were stocked on the ship?

3. a. Nutritionists (people who study balanced diets) place food in five groups the groups are listed below. Place the foods taken on the whaling ship in their proper place.

MEATS (including beans, peas, peanut butter)	FRUITS & VEGETABLES	BREADS & CEREALS	MILK	EXTRA FOODS (soda pop, candy, etc.)

b. Which group had the fewest foods? What is one possible reason for this group having so few listings?

c. Do you think the sailors had a lot of variety in their meals? What foods not listed might they have been able to add to their diet?

4. Duck is a fine, white canvas-like material. What are two possible uses for duck on a whaling ship?

a.

b.

5. Copper sheathing is used to protect wood from attack by marine "worms." Where, do you suppose, the copper sheathing was "worn" by the ship?

6. What were the try pots?

BLOOD MONEY

Part II

The costs shown in Part I had to be paid before the ship sailed. Other costs had to be paid when the trip was over. The wages for the captain and crew made up most of the after-cruise expenses. The following are the wages for one seaman's four year voyage in 1849.

Sailor's share in money		$262.25
Less:	Fitting, shipping, medicine chests	10.00
	10% discount on share	26.22
	3% insurance on share	7.86
	Money advanced for voyage	70.00
	Interest on same	16.80
	Cash advanced on voyage	30.00
	Interest on same @ 1%/month	7.20
	Clothing drawn	40.00
		$208.08
Amount paid at end of voyage		$ 54.17

1. This figure is called the gross wages. (The "before tax" figure).

   a. What did this sailor make (gross for each year of the four year cruise?

   b. How much was this per day? (Hint: There are 365 days per year.)

2. This figure and the "Clothing drawn" help pay back what the owner spent to outfit the ship. Who also collected the other "deductions" from the seaman's pay?

3. a. How much cash did the ship's owner really have to pay this seaman?

   b. The total cost for a seaman was the amount paid in cash at the end of the voyage plus fitting and clothing expenses. What was the total amount it cost the owner for 4 year's of this sailor's life?

4. a. From Part I, what was the total combined cost of vessel and outfit? ________________.

b. The whaleships brought in an average of $16,000 a year. What would be the value of the cargo for this four year cruise? ________________.

c. Total crew salaries amounted to $10,000. How many similar four year cruises would be required to pay for the entire ship, outfitting and salaries? ________________.

5. Ship's owners took advantage of their crews. Owners made from 25 to 50 percent a year clear profit on their investments.

a. At 50% profit, how many years would be required to pay off the investment?

b. [illegible]ut what annual percentage did the owner described above in question 4 earn?

[illegible]nt: annual percentage = $\frac{\text{annual income to owner - total of sail[illegible] annual salaries X 100)}}{\text{total combined cost of vessel and outfit}}$

TEACHER BACKGROUND - Count 'Em High, Count 'Em Low

The International Whaling Commission (IWC) is the only worldwide organization with any responsibility for controlling the whaling industry. Its membership is on a voluntary basis, numbering 17 countries, including Japan and Russia, both of whom still hunt the (great) whales. Partly because the presence of these two nations forces compromises, critics argue that the IWC represents a vested interest for the whaling industry. There are many countries that are not members of the IWC that allow whaling, as well as 'pirate' whalers who will take any type of whale in any region, indiscriminately. Moreover, the IWC has no powers of enforcement, and members can opt out of decisions made at meetings, if they wish, within 90 days.

The scientific committee of the IWC makes estimates of whale populations and sets harvest quotas based on these estimates. The theory is that a population can replace itself if not too many of its numbers are taken. The maximum sustainable yield (MSY) is the largest number of animals which can be taken from a population and still allow the remaining population to make good the deficiency. The calculations of the MSY however, requires a knowledge of the original population size. Present whale populations are difficult enough to estimate, and estimates of the original populations of the great whales are not much more than educated guesses. These guesses are made on the basis of sightings by whalers (a statistic suspect in itself), by mark and recapture techniques and by comparing the number of whales caught, to the effort involved. Conservationists have many criticisms of the statistical assessments of the IWC. One problem is that the MSY estimate is a technique used to regulate the fishing industry, but may not be useful to control whaling. Fish have a much higher reproductive rate and can more easily replace their numbers than can whales. There is also evidence that social disruption (such as killing members of a group) may reduce reproductive ability of whales. Some studies seem to indicate that below a certain population density, whales may never be able to reproduce enough to recover their losses.

At the present time the IWC has bans on the hunting of blue whales, southern right whales, grey whales, bowheads and humpbacks. Species that the IWC places quotas on are sperm whales, mink whales, fin whales, sei and Bryde's whale. A 10 year moratorium on all whaling has been suggested to allow populations to recover, but it remains to be seen if Russia and Japan will agree to such a ban, before the remaining great whales become as scarce as to be commercially unexploitable.

Perhaps the most complete work dealing with whale population estimation is:

Conservation and Management of Whales by K. Radway Allen (1980), University of Washington Press, Seattle. 107 pages.

Duplicate the activity pages. One set is recommended per student. This activity is best performed by pairs of students, as an in-class assignment. Part I serves as an introduction to the mechanics of "whale" sampling. You might introduce this section with a brief discussion of the role of models in science. Your students will be using red and white beans in a model of the sperm whale population of the North Pacific Ocean. Before class begins, prepare brown paper bags of "whales." Add about 50 ml of white beans plus 100 ml of red beans to each bag. The exact numbers and proportions are not critical.

Part II is slightly more complex than Part I and requires that your students carefully read and follow the directions. They may profit from an on-the-board demonstration of the proper way in which to complete the Data Chart. Plan to discuss the Analysis and Interpretation sections after your students have finished the activity.

KEY

Part I

1. Most of your students will be willing to admit that their estimates are not likely to be very accurate.
2. While answers will vary, the estimates are basically guesses.
3. a. Most students will not think that the observers see all of the sperm whales.
   b. Answers will vary. One technique would be to estimate the portion of the ocean surveyed and from this information extrapolate the number of whales in the larger ocean.
4. a. Answers will vary. One possible way would be to take a bigger handful, ie. a larger sample.
   b. Answers will vary. One possible improvement would be to have more observers, ie. more data (again, a larger sample).

Part II

1. & 2. Answers will vary but should appear on the Data Chart and be mathmatically sound.

3. a. Your student's best estimates of the sperm whale population will probably be the estimate from Trial 10.

b. Generally the last four estimates will be more similar to each other than the first six are to each other.

c. Answers will vary depending upon the population estimates.

d. In most instances the average will be the new best estimate for the sperm whale population. Exceptions might occur where single estimates are appreciably different and suspect. In cases where one estimate is suspect, an average based on three estimates would prove a better estimate.

4. Answers will vary. If you have counted the white beans before their addition to the bags, you will know the actual numbers.
5. Answers depend upon the experimental results.
6. The mark and recapture technique gives a better estimate of the whale population than the direct count (barring the rare lucky guess)
7. a. Birth causes the population to increase.

   b. Death causes the population to decrease.

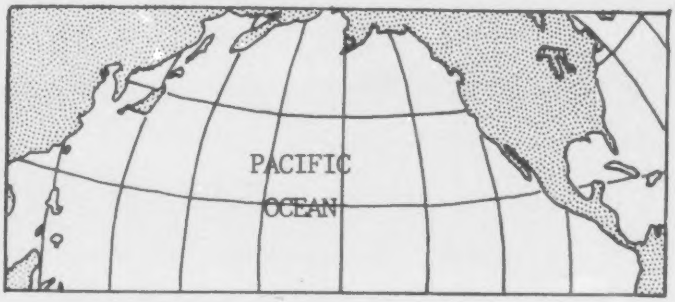
   c. Because of the adverse impact of whaling, it is not safe to assume that the number of births equal the number of deaths in a sperm whale population. These questions are included to allow you to remind your students that our simplistic population model did not take all of the basic factors into consideration.
8. The safest number at which to set the sperm whale quota, based on the questionable data available, is zero. Quota numbers greater than the reproductive recruitment of the population threaten the sperm whale with extinction. It seems to the author that it is best to err on the side of conservatism in establishing quotas. New data on population size may allow us to establish higher quotas. It is always possible to increase the quota if we find there are more whales than we currently think. It will never be possible to recreate a sperm whale if they're hunted to extinction.

KEY WORDS

appropriate
average
baleen whales
calculated
capture
column
compute
data chart
direct counting
estimate
formula
individual
International Whaling Commission
Lincoln Index
mark and recapture
percentage
population
quota
ratio
release
reliable
sample
sperm whale
techniques

COUNT' 'EM HIGH, COUNT 'EM LOW

Just how many whales are there anyhow? The International Whaling Commission must establish quotas (numbers of whales that may be killed). They need to know "how many." Well, that should be simple enough, just count the whales. In the following activity you will have a chance to see just how easy it is to estimate population size. We are interested in making our best "guess," or estimate, of the number of sperm whales in the North Pacific.



RARE & ENDANGERED CETACEAN SPECIES

- Black right whale
- Bowhead whale
- Sei whale
- Fin whale
- Blue whale
- Humpback whale
- Grey whale
- Indus susu (dolphin)
- Sarawak dolphin
- Pygmy killer whale
- Cochito
- Spectacled porpoise
- Dall's porpoise
- Sperm whale
- Pygmy sperm whale
- Dwarf sperm whale
- Tasman beaked whale
- Northern bottlenose whale

Materials:

paper bag

"sperm whales" (white beans)

"baleen whales" (red beans)

data sheet

pencil or marker

Procedure:

Part I

1. Obtain a paper bag with an unknown number of whales. Place your initials on the bag. DO NOT look into the bag. The bag represents the North Pacific Ocean. The bag contains the population of whales you are interested in counting. Reach into the bag and pull out a "pinch full" of whales (no more than 2C or 30). The white individuals are sperm whales. The red individuals are baleen whale species.
2. Count the number of "sperm whales"(white). Record this information on the data chart. Do the same for the "baleen whales."
3. You have now taken a sample of the whale population. From your sample, estimate the total number of sperm whales in the North Pacific. Record your estimate on the data sheet.

Analysis and Interpretation:

1. As an International Whaling Commission scientist, how accurate do you think your estimate is?

2. On what did you base your estimate?

3. Does this seem like a very reliable way to estimate the sperm whale population in the North Pacific? Real whale population sizes are estimated using a similar technique. This method is called direct counting. Observers travel through the waters in which whales live. As they travel they count the whales.

   a. Do you think they see all of the sperm whales?

   b. They don't think so either. They have to guess the percentage of whales they see. How might you go about guessing the percentage?

4. a. How might you improve your estimate?

   b. How might scientists improve their estimates?

Part II

How can scientists improve their estimates? In 1930, F.C. Lincoln described the mark and recapture technique for estimating animal populations. The method involves the capturing, marking and releasing of animals into a given population. These marked animals supposedly return to the places they had in the original population as they had before capture. After a certain time, a sample of the population is taken. An estimate of the total population is computed by the ratio of marked to unmarked individuals.

Mark and recapture methods are used to estimate whale populations. The following activity will give you an opportunity to use the Lincoln Index mark and recapture method.

Procedure:

1. Return the sample of sperm and baleen whales you counted in Part I to the North Pacific Ocean bag. Again, reach into the bag and pull out a "pinchfull" of whales (no more than 20 or 30). Recall that the white individuals are sperm whales. The red individuals are baleen whale species. Try to maintain this sample size with each grab into the North Pacific Ocean.
2. Count the number of sperm whales you grabbed out of the bag (trial one). This number will be designated by the symbol "C" for capured. Enter this number in the column indicating number captured for Trial #1, on the Data Sheet.
3. Once the sample has been counted, mark a simple line on both sides of the bean.
4. Count the number of marked sperm whales . Enter this number on the Data Sheet (Trial #1) in the column labeled "*Newly marked and released in each trial.*" For Trial #1, this figure will be the same number you entered in Column "C". (See sample Data Sheet)

5. After all the sperm whales in this sample have been marked and counted, release them back into the North Pacific bag.
6. Shake the bag well to insure that the newly marked sperm whales "swim" randomly back into the population.
7. You are now ready to begin your second catch (Trial #2). BEFORE beginning, look at the first column (Column "M") of the Data Sheet. It reads, "*Total marked in population at start of each trial.*" In this case, this would be the number of animals you marked in Trial #1. Enter this number in Column "M".
8. Now proceed to grab a sample of whales for Trial #2. Use the same technique as you did in step 1. Record this number in Column "C", Trial #2
9. If there were any sperm whales already marked on this capture, enter their number in Column "N".
10. Mark the rest of the sperm whales in the sample. Count them and enter the number in the column labeled "*Newly marked and released in each trial.*"
11. For now, leave blank the last two columns of your Data Sheet.
12. Now begin Trial #3. Remember, Column "M" is to be computed BEFORE you grab your sample. ALWAYS compute "M" before each trial by adding the "M" for the previous trial and the column entitled "*Newly marked and released in each trial*" of the previous trial.

For example, look at the sample Data Sheet. The figure for "M" in Trial #3, is the sum of "M" and the "*Newly marked and released in each trial?* column of Trial #2.

"M" for each trial is the TOTAL number of individuals you have marked in the population and have put back into the bag. "M" gets greater as you do more trials.

13. Once "M" has been calculated in Trial #3, you may grab a sample and proceed as you did in previous trials. Count, mark, release, and fill in the appropriate columns.
14. Continue the above process through 10 trials. After the tenth trial, return the newly marked sperm whales to the bag. Set the North Pacific bag aside.

Analysis and Interpretation:

Lincoln's Index states that the total marked individuals in the population is to the total population as the number of marked individuals captured in the sample is to the number of individuals captured in the sample. Confusing? It may help to write this ratio as follows:

$$\frac{\text{Total marked in Population}}{\text{Total number in Population}} = \frac{\text{Number marked in sample}}{\text{Number of Individuals in sample}}$$

$$\text{(OR)} \qquad \frac{M}{P} = \frac{N}{C}$$

We are trying to estimate (P), the population size. Since we know (M), (C) and (N) from our sampling, we can rewrite the formula:

$$P = \frac{(M) \times (C)}{N}$$

1. For trials 1 to 10 fill in the M X C column.

2. For trials 1 to 10 estimate the population (P) by dividing M X C by the appropriate N.

   For example, look at the third trial on the sample data sheet. M X C equals 1000. Divide 1000 by N (in the case of trial #3, N = 2) to obtain a population estimate of 500 sperm whales, in the North Pacific Ocean.

3. a. What is your best estimate of the sperm whale population? ____________

   b. Are the last four population estimates more similar to each other than the first six are to each other?

   c. If the answer to (b) is yes, determine the average of the last four estimates. (This is easy: Add the four estimates and divide the total by four). Record the average. ____________sperm whales.

   d. Generally, the average gives us the best estimate. What is your best estimate of the sperm whale population? ___________sperm whales.

4. The moment of truth has arrived. Pour out your bag's contents. Count the number of sperm whales (white). Record the actual number on your Data Sheet, and here:

   Actual number = ______________sperm whales.

5. The actual number of sperm whales is less than / greater than the estimated number of sperm whales. (Circle the correct answer).

6. Did the mark and recapture estimate give you a better estimate of the whale population than the direct count?

7. These estimates do not include birth and death.

   a. How does birth influence population?

b. How does death influence population?

c. Is it safe to assume that the number of births equal the number of deaths in a sperm whale population?

8. Scientists also use other techniques. Even so, many scientists say reliable population estimates are not available. With this in mind, what is the safest number at which to set the sperm whale quota? Why?

DATA CHART

Part I

Sperm whales (white) ____________.

Baleen whales (red) ____________.

Estimate of total population of sperm whales in North Pacific Ocean ____________.

PartII

Sample Data Sheet:

TRIAL #	TOTAL MARKED AT START OF EACH TRIAL (M)	NUMBER IN SAMPLE (C)	NUMBER ALREADY MARKED IN CAPTURED SAMPLE (N)	NEWLY MARKED & RELEASED IN EACH TRIAL	M X C	ESTIMATED POPULATION (P)
1	0	23	0	23	0	0
2	23	28	1	27	644	644
3	50	20	2	18	1000	500
4						

Data Sheet:

TRIAL #	TOTAL MARKED AT START OF EACH TRIAL (M)	NUMBER IN SAMPLE (C)	NUMBER ALREADY MARKED IN CAPTURED SAMPLE (N)	NEWLY MARKED & RELEASED IN EACH TRIAL	M X C	ESTIMATED POPULATION (P)
1	0					
2						
3						
4						
5						
6						
7						
8						
9						
10						

Actual (Counted) number of sperm whales ____________________.

OFFSHORE OIL PRODUCTION

TEACHER BACKGROUND - December 10 and WHO NEEDS ENERGY? and IT CAME FROM BENEATH THE SEA.

Over the past half century, there has been a dramatic increase in the importance of oil as a source of power. "December 10" and the five activities which follow it provide your students with an opportunity to examine some of the issues concerning offshore drilling. Energy production and use are topics laden with controversy. Provide a classroom atmosphere conducive to rational discussion based on facts as well as on opinion.

"December 10" provides an introduction to the topic through a brief recollection of the Santa Barbara Oil spill of 1969. The Santa Barbara oil spill is discussed in more detail in "Trouble in the Channel." The second activity, "Who Needs Energy?," is a personal energy profile designed to focus your students' attention on the role of oil energy in their lives. "It Came From Beneath The Sea" provides a look at offshore oil exploration and production while offering a brief glimpse at the incredible technology employed by the oil industry. "Oil on Water" which follows "Trouble in the Channel" provides your students with opportunities to clean up simulated oil spills. The topic is concluded with "Point/Counterpoint," a one minute "debate" in which pairs of students provide evidence supporting opposing positions on controversial issues.

In all of the above activities, it is important that you provide sufficient factual information to allow your students to reach logical conclusions. The issues are most pressing and serious. The world's production of oil is something on the order of 600 billion gallons per year. About 60 percent of this amount is moved at sea, or about 360 billion gallons. In addition, oil constitutes about 60 percent of all goods transported at sea. All of this 360 billion gallons is loaded and unloaded, and nearly all of it passes through restricted shipping lanes at least once.

A minimum estimate of the amount of oil lost at sea states that 0.1 percent of all oil moved at sea is spilled, or about 360 million gallons. The actual influx of oil into the sea is much higher, due to accidents in the extraction of oil from the sea floor, as at Santa Barbara, the sloppy use of fuel oil by ships at sea, or the oil introduced into the ocean by sewage wastes.

Oil and oil products are very complex mixtures of chemicals. Low-boiling saturated hydrocarbons produce anaesthesia and narcosis at low concentrations and cause cell damage and death at higher concentrations.

Inevitably, no matter what kind of oil is spilled, thousands of marine birds are killed, especially species which live in close association with the sea surface, rather than birds which fly much of their time or those which wade along the shore. These surface-dwelling birds are totally exposed, when they dive for food. Their feathers become coated with oil and their insulating ability is greatly reduced. They become wet and cold and then lose a great deal of energy trying to keep warm. They attempt to clean themselves by preening, ingesting toxic substances from the oil in the process. If and when they arrive on shore, they are nearly immobile, cold, wet, starving, and sick. Very little can be done to save them.

Other immediate effects of oil on marine life after a major spill depend on the type of oil, where it is spilled, how quickly it reaches the shore, and what kind of shore it encounters. The experiences with each major spill have been different.

Biologists are beginning to discover that the problems caused by oil spills on the sea are not limited to the immediate kill of marine birds, the immediate toxicity to shallow-water marine life, the smothering of intertidal animals, or the tainting of shellfish. Research demonstrates that, even eight months after a spill of fuel oil, oil constitutents, are still present in bottom sediments, both inshore and offshore. They are also present in marine organisms, including commercially important clams.

Half of the world's catch of fish comes from 0.1 percent of the ocean surface. Large oil spills and smaller daily spills in coastal waters could contaminate these highly productive regions.

In addition, the extent of pollution of the open seas causes considerable concern.

Thor Heyerdahl, on his trip across the Atlantic Ocean during the summer of 1970, reported this oceanwide pollution. "Clots of oil are polluting the midstream current of the Atlantic Ocean from horizon to horizon....During the 27 days of sailing so far, oil lumps in varying quantities have been observed uninterruptedly every day....It is entirely possible that the pollution area spans the entire ocean, from the coast of Africa to the coast of Tropical America."

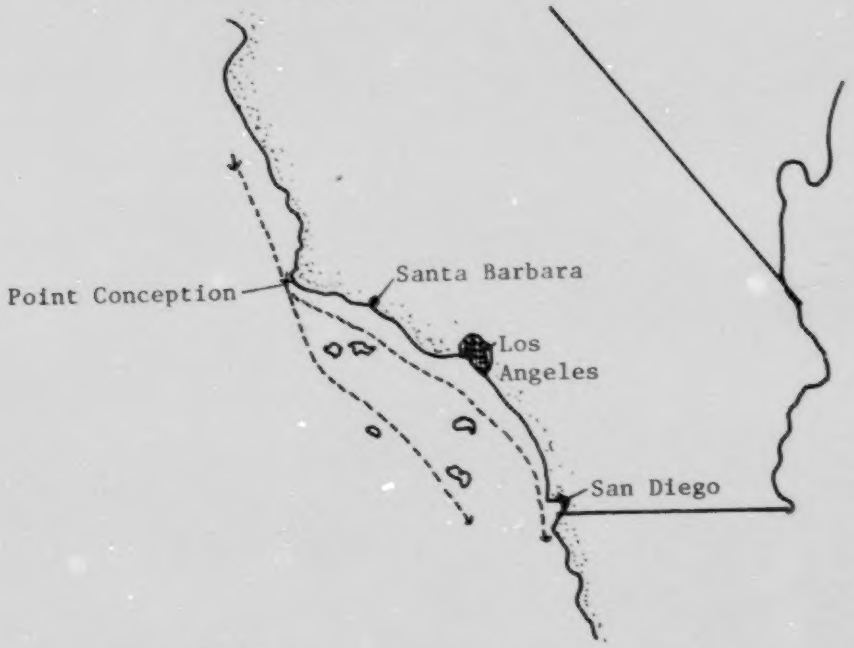
We are on the horns of a dilemma: Increasing demands for oil increase the risks of oil spill. Necessary efforts to meet these demands need to be coupled with a public policy which seeks to prevent continued contamination of the sea by oil, whether in drilling, transport, sewage disposal, or in use as a fuel.

Duplicate the activity and text pages. One set is recommended per student. "December 10", "Who Needs Energy?" and "It Came From Beneath The Sea" are best accomplished by individual students as homework or in-class assignments. A brief discussion of "Who Needs Energy?" should immediately follow its completion by your students. During the discussion emphasize the myriad of ways our everyday lives are dependent upon oil energy and oil derived products. Follow the discussion with an introduction to "It Came From Beneath The Sea." Again, plan to allow time for a discussion of the text questions found in "It Came From Beneath The Sea."

KEY

December 10

1. A correctly marked map is shown below.

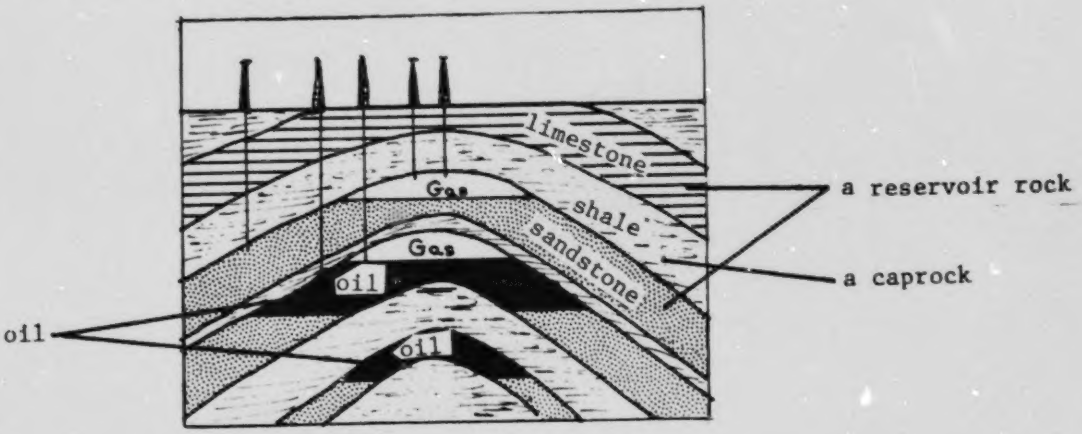


Who Needs Energy?

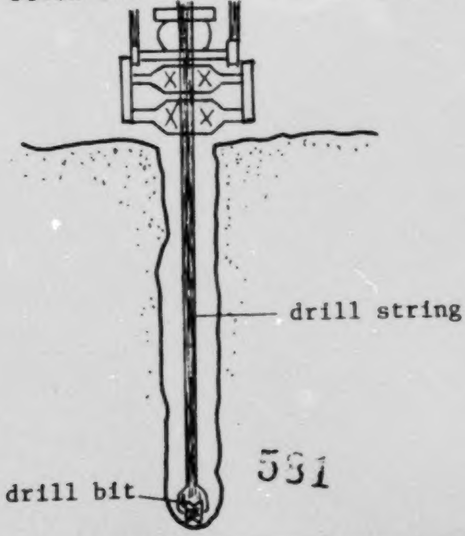
There are no "right" answers for the questions posed. The questions are presented to encourage reflection and discussion.

It Came From Beneath The Sea

1. Experts think that [✓ *more than*] / *less than* 26 percent of the world's known reserves will come from beneath the seas. The correct answer is circled.
2. The first off-shore wells were drilled from *rigid platforms* .
3. a. As we are forced to go deeper for oil, the cost of the oil increases.
   b. In the future, the difference between the cost of solar power and oil power will be *more* / [✓ *less*] . (The correct answer is circled).
4. The drawing below is correctly labeled.


limestone
Gas
shale
sandstone
Gas
oil
oil
oil
a reservoir rock
a caprock

5. The explosions produce sound waves which travel downward through the seabed rocks. Each layer reflects the wave to a different degree. The variations in the reflections show the structure of the rocks beneath the sea.
6. The drawing below shows a correctly labeled drilling rig.


drill string
drill bit

7. The four types of oil exploration rigs mentioned are:
   a. template rig
   b. jack-up rig
   c. semisubmersible rig
   d. drill ship rig
8. A production platform has *fewer* /[✓ *more*] wells than an exploration platform. (The correct answer is circled).
9. One item, mentioned in the text, that adds to off shore drilling is the cost of the fleet of work boats. Off shore rigs also have to provide food and housing for the workers.
10. Two methods used to transfer oil and gas to shore include:
    a. pipeline
    b. tanker
11. While answers will vary, most will state that bad weather will make tanker loading more difficult thereby increasing the likelihood of oil spills.
12. This question is provided by way of introduction to the next activity, "Trouble in the Channel." Four possible places spills could occur in the oil production process include:
    a. at the well head on the sea floor
    b. at the well head on the platform
    c. during on-platform processing
    d. during shipping from platform to tanker or pipeline
    e. during transfer from pipeline to tanker
    f. during transfer from tanker or pipeline to refinery

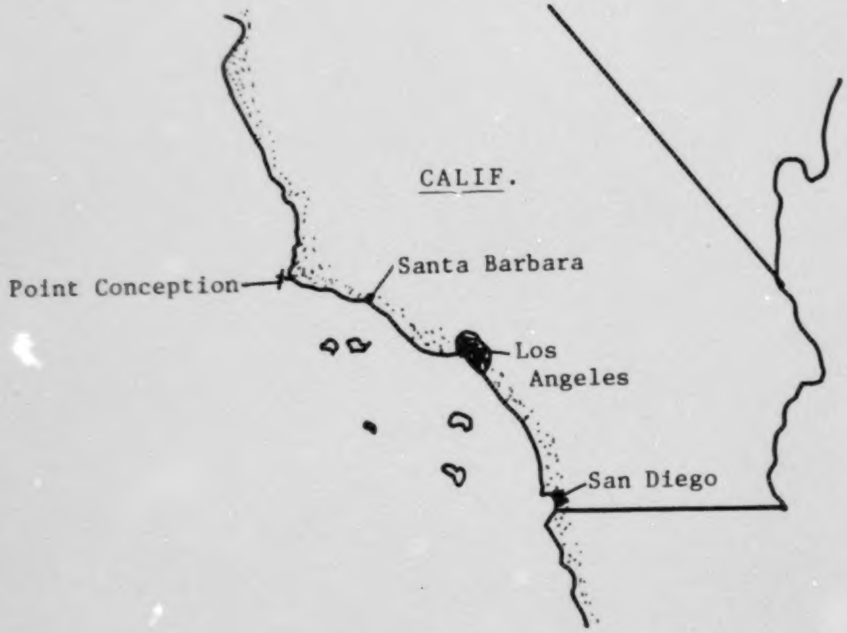
KEY WORDS

accessibility
bit
blow out
buoy
caprock
casing
commercial
continental shelves
crude oil
derrick
deposits
develop
drill
drill string
energy
estimate
exhausted
exploration
harvest
hydrophone
impermeable
jack-up rig
juts
major
minerals
mobile
moorings
nuisance
offshore
oil
petroleum
pipeline
platform
pressure-control devices
processing
production
profile
propellers
refineries
reflection
reservoir
rig
rigid
seismic survey
seep
semisubmersible rig
senses
sound waves
source
structure
submerged
tap template
traditionally
transporting
valves
well

"If seven maids with seven mops
Swept it for half a year,
Do you suppose," the Walrus said,
"That they could get it clear?"
"I doubt it," said the Carpenter,
And shed a bitter tear.

DECEMBER 10

Our whale has now traveled more than 4,000 miles. It has been more than two months since she has seriously eaten. She moves south along the California coast. Her senses of taste and smell locate the mouths of rivers. Her senses also locate other gray whales swimming south. She passes close to land where the land juts into the Pacific Ocean. She swims farther off shore as she passes coastal bays.



In the company of other whales, she nears Point Conception west of Santa Barbara. Here, some of her companions swim directly south. Returning to the coast, this group follows a chain of offshore islands near San Diego. Our whale hugs the coast line following the second main group of whales.

1. Use dotted lines to trace the paths of the two major groups of gray whales from Point Conception to San Diego.

South of Point Conception, she tastes a strong flavor. The flavor is not as strong as in years past. But it is still present. The flavor belongs to oil.

In gray whale time, it did not happen many years ago. In January of 1969, an oil production platform off the Santa Barbara coast had a blow out. Some 700,000 gallons of oil were released into ocean waters before the leak was controlled. In the next activities you will have an opportunity to examine offshore oil production.

WHO NEEDS ENERGY?

Why do we need to drill under the seas for oil? How does the energy from oil affect our lives? Let's begin to answer these questions by filling out the personal energy profile below.

1. Right at this moment, what sources of energy are you using?

2. What sources of energy did you use today?

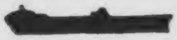
2. What would happen if one of these sources were cut off right now?

4. What would you do about its being cut off?

5. Which sources of the energy are marine in origin?

IT CAME FROM BENEATH THE SEA

No question about it. We use energy from oil every day. We are an "oil-based" society. People traditionally think of the harvest of the sea in terms of food. Recently, attention has been turned to another harvest: the harvest of the minerals that lie beneath the sea. An estimated 26 percent of the world's known oil reserves are submerged beneath the seas. Some experts think exploration will greatly raise that percentage. An increasing amount of the world's oil will be drawn from beneath the ocean. The end of the oil age will occur when the oil in the deeper parts of the ocean is exhausted.


16,419 deadweight tons

117,000 D.W. tons

1. Experts think that more than/ less than 26 percent of the world's known reserves will come from beneath the seas. (Circle the correct answer).

400,000 D.W. tons

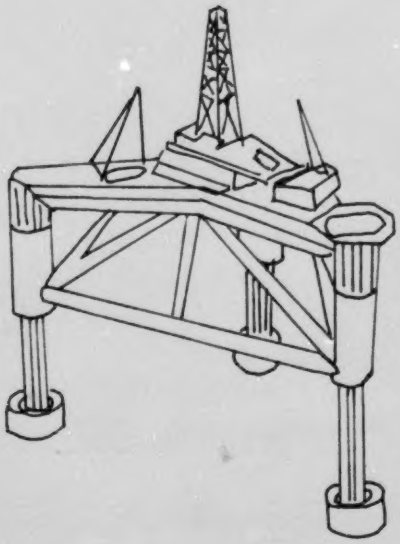
Oil in the Santa Barbara channel seeped from the sea floor long before the first Europeans arrived. For centuries this seeping oil was considered a nuisance. As on shore oil became

1,000,000 D.W. tons

more difficult to locate, explorers looked to the sea. Recalling the oil seeps, the area near Santa Barbara looked promising.

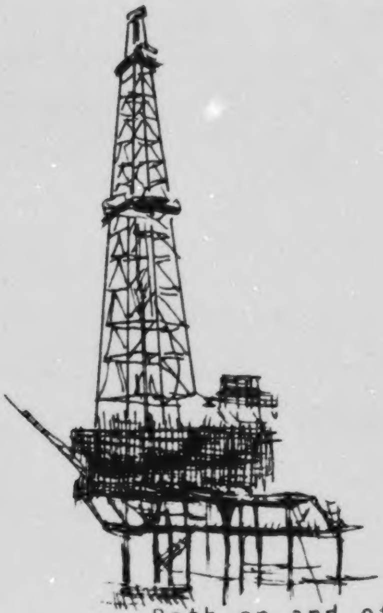
Before wells could be drilled many problems had to be solved. The first offshore oil wells were drilled from rigid platforms built in shallow water.

The next development in offshore oil exploration happened in the Gulf of Mexico. During the summer and fall of 1947, the first undersea well was completed from a mobile (moveable) platform.



Exploration for petroleum is taking place on all continental shelves except the Antarctic. There is an increasing demand for oil. As a result it is important to know the success rate in finding new fields. It is also important to know the time involved in the discovery, and the development of the field for production. This knowledge is important in predicting the role of offshore oil in future energy supplies. Of course, the major problem still is that we do not know where oil is located. Many wells that are drilled find no oil. To tap more underwater oil deposits, wells will have to be drilled in deeper water. It now costs seven times more to drill for oil offshore than on land. As drilling begins in deeper water, the costs rise even more. Even if there are large submerged oil deposits, they will be expensive to develop.

3. Solar power now costs more than oil power.
    a. As we are forced to go deeper for oil what happens to the cost of the oil?
    b. In the future, the difference between the cost of solar power and oil power will be more / less. (Circle the correct answer).



The Search For Oil

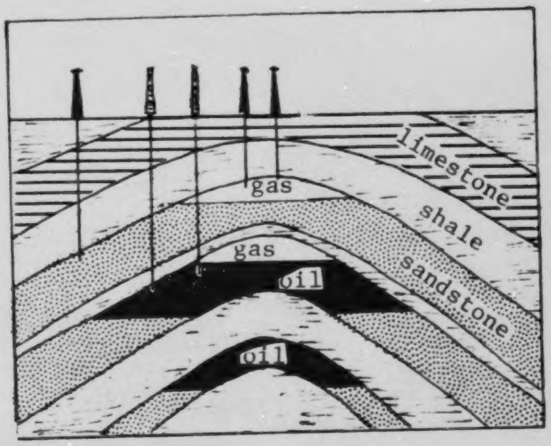
All the world's major oil fields on land have probably been found and are being worked. It is the oil that lies underwater that interests us. Petroleum, or oil, comes from the decay of ancient marine plants and animals.

Both on and offshore, explorers for oil are looking for the same types of rocks and structures. They look for:

a. a source rock rich in plant and animal remains.

b. a reservoir rock (sandstone or limestone) into which the oil and gas can move.

c. an impermeable seal (non-leaking) seal or caprock (shale or salt) for the reservoir. The caprock traps the oil or gas in the reservoir.



4. On the drawing above label the three features necessary for oil production:

a. oil

b. a reservoir rock

c, a caprock or seal rock

Geologists searching for oil set off controlled explosions on the surface of the sea. The sound waves from the explosion move down through the seabed rocks. Each layer reflects the wave to a different degree. A series of instruments, called hydrophones, record the sound waves. The variations in the reflections show the structure of the rocks beneath the sea. This process is called a seismic survey.

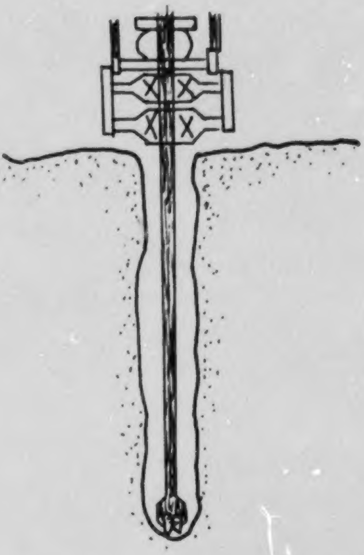
5. How do explosions help geologists determine the structure of the rocks beneath the sea?

Drilling For Oil

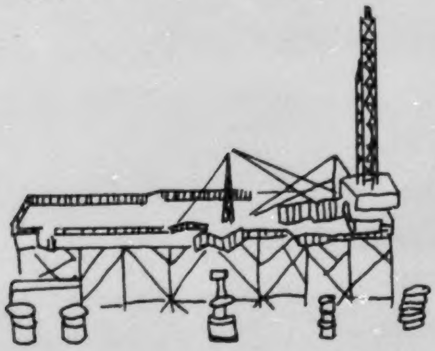
Experts study the results of the seismic survey. If they think the chances of finding oil are good, they drill a well. A well is really a deep hole and is the only way to determine the presence of oil.

The majority of the holes drilled contain only water or uneconomic amounts of oil. A drilling bit is used to cut through the rock. The bit is connected to a pipe called the drill string. Engines drive the drilling bit into the earth. Pipes are added to the drill string as it goes down. Mud and rock come up the drill string. If the drillers find oil, it rushes up the drill string. To keep the oil from gushing uncontrollably up the pipe, drillers use complex systems of pressure-control devices. Just discovering oil proves nothing. What counts is the amount and accessibility of the oil. Engineers test to see whether a field is worth commercial exploration. If it looks promising, more wells will be drilled. These wells are placed to determine the size and shape of the field.

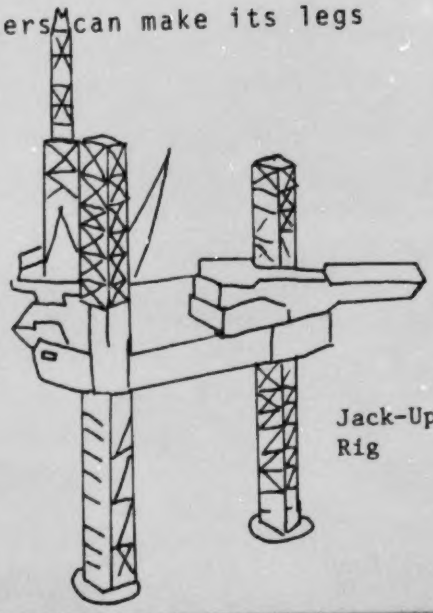
6. On the drawing to the right label:
   a. the drill bit
   b. the drill string



Drilling in the sea requires special equipment. Before 1953, offshore drilling rigs were confined to shallow waters. The development of the "jack-up rig" allowed exploration in water up to 300 feet deep. The legs of the jack-up rig set on the bottom of the sea. Workers can make its legs taller or shorter.

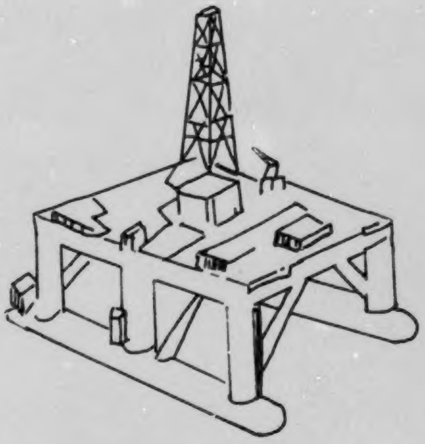


Early offshore rig



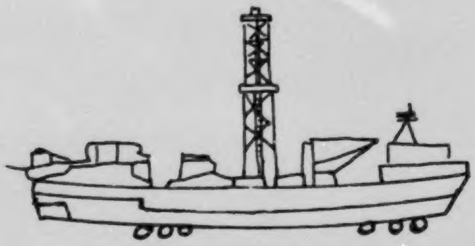
Jack-Up Rig

In 1962 there was another breakthrough, the semisubmersible rig. Special legs, filled with air, let it be floated out to the drilling site. There it is held in place with anchors.



Semisubmersible Rig

In 1971 the first modern drill-ship was used. It has a derrick (drilling tower) built on its deck. The drilling bit and the drill string go through a hole in the bottom of the ship. Other drill-ships had been in use for nearly 20 years. This advanced type is able to stay over a well in deep water by using directional propellers. These mobile drilling rigs are sent all over the world.



Drilling Rig

7. What are four types of oil exploration rigs?

a.

b.

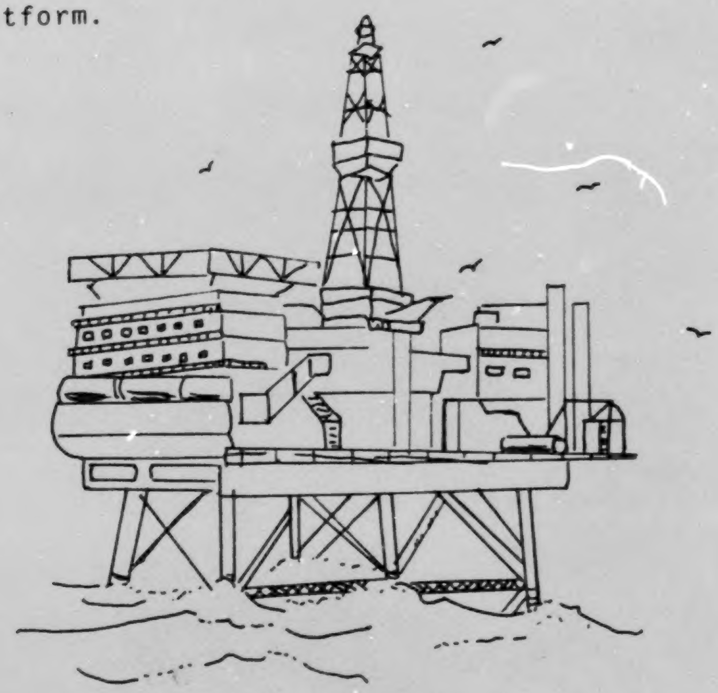
c.

d.

In the ocean, these drill rigs determine the size and shape of the field. Oil company experts then decide whether to develop the field. Development means several years of costly drilling from a fixed platform. Plans must also be made to move oil from the well to refineries.

Drilling For Production

Drilling for production is expensive. A production platform must be built to support drilling equipment for several wells. The platform must also hold oil and gas processing equipment. In addition, it must be strong enough to last for 30 years. The base of the platform is built on land. It is pulled out to sea on its side by tugboats. At the well it is turned over and set in the sea. Next the production platform is built. Cranes on barges put the decks in place. They also lift buildings, a drilling derrick, and processing equipment onto the platform.



8. A production platform has fewer / more wells than an exploration platform (Circle the correct answer).

The production platform is like a factory. Everything needed to get oil up from the well and ashore is on board the platform. When the platform is ready, the wells are drilled. The biggest modern platforms may have two derricks drilling simultaneously. These big platforms have double crews working round the clock. There may be living quarters for as many as 140. As many as 60 wells may be drilled outward from each platform. A fleet of work boats and helicopters bring in pipe, casing, cement, mud, workers, fuel and food.

9. Drilling oil wells is very expensive. Offshore wells are more expensive than land wells. What is one item oil companies must buy for offshore drilling they don't buy for land drilling?

After the wells are drilled, the production equipment is put in place. This includes a complex group of control valves. The valves called the Christmas tree, shut off automatically if there is any damage to the well. On the deck of the platform the various parts of the crude-oil or gas mixture are separated. The oil and gas are transferred to a tanker or pumped through a pipeline to the shore. Once all the equipment is working, the complete platform can be automated. The platform is then controlled from a computer onshore. Production platform installation takes 6 to 8 years.

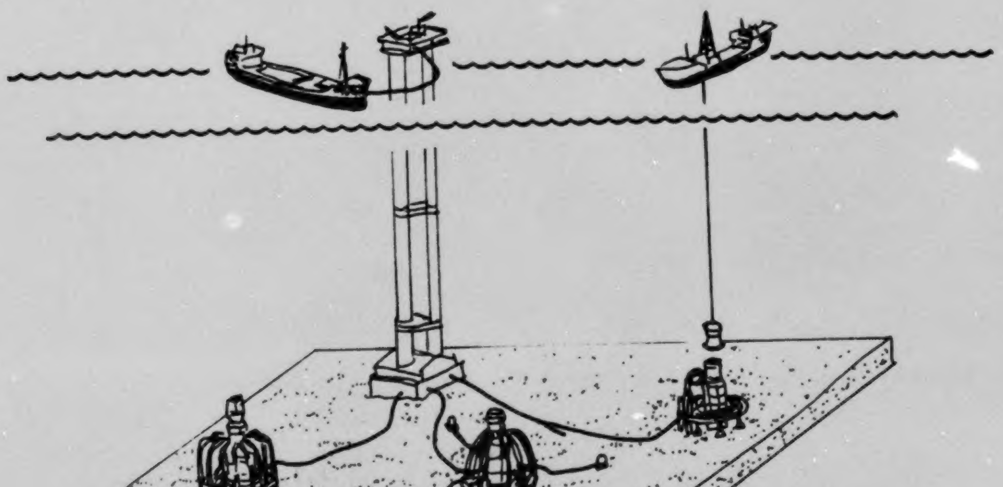
10. What two methods are used to transfer oil and gas to shore?

    a.

    b.

Getting The Oil Ashore

Wells have been drilled. Oil and gas are flowing to the platforms. The next challenge involves transporting the crude oil and natural gas from the offshore wells to coastal areas. Within a field, pipelines are usually laid from all the platforms to a central point. These pipelines are under water. From the central point, a pipeline to shore may be laid. If the field is far offshore, the oil is taken to shore by tanker. Tanker moorings are anchored to the sea bed. A floating hose carries the oil from the sea bed through the mooring buoy to the tanker.



11. How do you suppose bad weather affects loading oil on tankers?

When the oil reaches shore, it moves to refineries. Refineries process the crude oil into gasoline, heating oil and many other products. That quart of oil you buy at the store has a very long and complicated history. It's had its beginning as living plants and animals. Many hands have worked to produce the oil. Much money has been spent to find and make it. Please, use the oil wisely.

12. Oil production is complicated. There are many places where oil spills can occur. List four possible places where spills could occur.

    a.

    b.

    c.

    d.

TEACHER BACKGROUND - Trouble in the Channel

The Santa Barbara oil spill of 1969 had far reaching effects on environmental concern and legislation. Since your students are too young to have first-hand recollections of the incident, "Trouble in the Channel" excerpts news magazine articles from the weeks following the oil spill. Time and Newsweek may be challenging reading for your students. To reduce the difficulty and to focus your students' attention on the most critical issues, the questions are referenced to the pertinent paragraphs. Read through the excerpted articles to reacquaint yourself with the particulars of the incident. If possible, provide your students with reference copies of the entire articles.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished by individual students as a homework or in-class assignment. The activity is broken into five parts. If you desire to spread the activity over two sessions, a logical break occurs between Parts III and IV. During your summary discussion of the questions, refer to the article to settle any disputes which may arise.

KEY

Part I

1. a. One thousand gallons of oil leaked into the water each hour.
   b. The well leaked for 11 days.
   c. $\frac{\text{1,000 gallons oil}}{\text{hour}} \times \frac{\text{24 hours}}{\text{day}} \times$ 11 days = 264,000 gallons of oil in 11 days.
   d. The Time article from 2/14/69 estimated that the oil spill covered *400* square miles. The Time article from the next week estimated that the oil spill covered *800* square miles. While the amount of oil was the same, the thickness of the layer determined the size of the area covered. The 800 square mile slick was thinner than the 400 square mile slick.
2. a. The drillers had dug down 3,500 feet before the well began leaking.
   b. When the leak occurred, the drillers were withdrawing the drilling pipe in order to replace the drilling bit.

c. A fissure played a major role in the oil leak. The blown well was initially capped. The cap caused a pressure build-up which was able to force oil out through the fissure.

3. The drillers tried to stop the leak by pumping barrels of plastic-like sealant down into the well hole. The technique finally succeeded after some 15,000 barrels of the sealant were expended.

Part II

4. Included among the techniques used to clean up the oil were the following:
   - a. Straw, talc and pearlite were spread along the beaches to soak up the oil.
   - b. Farm mulchers on barges spewed hay into the harbor and men in small boats pulled in the oil-soaked straw with garden rakes.
   - c. Pumpers tried to vacuum up concentrations of oil.
   - d. Two tugs pulled a V-shaped strainer through the water, concentrating the oil for transfer to a barge.
   - e. Detergents and chemicals were used initially.
   - f. Rocks (and their inhabitants) were steam-cleaned.

   Any four of the above will suffice.

5. The immediate impact of the oil spill on the tourist industry was to dramatically increase the number of tourists as curious people flocked to Santa Barbara to witness the disaster first-hand.

Part III - The Results

6. a. The birds were the first group of animals to suffer from the oil spill.
   - b. Surviving, oil-soaked birds were rushed to one of three centers nearby to be cleaned in a chemical solution, then carefully wrapped to prevent pneunonia and placed in warm pens to recover.
   - c. As of 2/14/60 (Time) about *two-thirds* of those treated had survived. By 2/21/60 (Newsweek) only *one-third* had survived.

7. Carl Hubbs, professor emeritus at Scripp's Institute predicted "a complete destruction of life in the intertidal regions along the shore for 20 miles, and considerable destruction for as many as 50 miles."

8. The oil spill completely stopped fishing in the channel. Shellfishermen found their catch alive but completely covered with oil.

Part IV - Politics

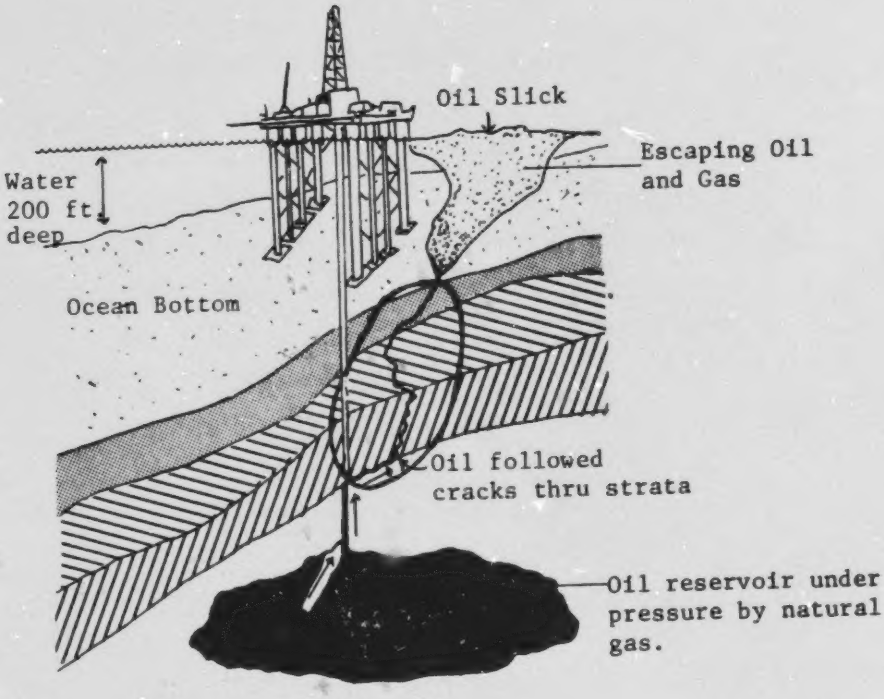
9. President Nixon promised to put fresh teeth in federal regulations to prevent oil spills and to produce far more stringent and effective regulations.
10. Walter Hickel responded initially by persuading all oil companies in the area to suspend operations. The next day he reversed his stand only to re-reverse his stand two days later and close the rigs down again.
11. In general, people thought that the oil spill would give legislation designed to protect water quality a better chance of passing than it would have had previously.

Part V - Four Months Later

12. The immediate effect of the oil spill was to kill untold small ocean creatures, hundreds of birds, lobsters, clams, mussels, and fish.
13. a. By way of refresher, Carl Hubbs predicted the channel would "never be quite natural again."
    b. The predictions were made on information learned from the wrecks of the *Tampico* and the *Torrey Canyon*.
14. The Santa Barbara oil spill was not the disaster it might have been. One reason was that crude oil is *more* / [✓ *less*] dangerous than refined oil. A second reason was that *much* / [✓ *little*] chemical detergent was used to clean up the mess. (The two correct answers are circled.)
15. This is a rhethorical question. No one knows what the long range effects of the oil spill may be on marine life.

Part VI - Looking Back

16. A correctly labeled drawing follows:


Oil Slick
Escaping Oil and Gas
Water 200 ft deep
Ocean Bottom
Oil followed cracks thru strata
Oil reservoir under pressure by natural gas.

What went wrong? A wornout drill was being pulled up when it passed a weak crack or fault. The oil blew out.

17. The Water Quality Improvement Act of 1970 oulaws *oil* *pollution* and provides a program to *prevent* and *control* oil spills.

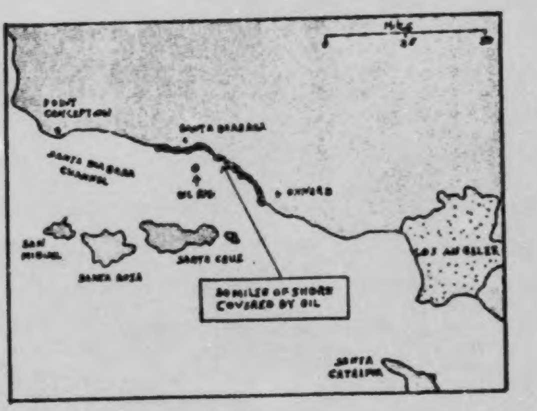
18. Answers will vary. This question is included as a springboard for discussion. Some feel that periodic disasters are the only way we can remind people of the importance of environmental protection. The author prefers to think that education can remind people of the importance without the "inconvenience" of having to relive historical disasters.

KEY WORDS

adjoining
affect
bit
blow out
chemical
contiguous
crisis

crude oil
detergent
disaster
drillers
estimated
fissure
forbids
immediate
impact
leak
legislation
marine life
navigable
pipe
prediction
prohibits
refined
revoke
oil pollution
oil production platform
safeguard
strata
square miles
techniques
tourist industry
water quality
Water Quality Improvement Act of 1970
well

Additional unknown vocabulary appears in the excerpted articles.



TROUBLE IN THE CHANNEL

In January 1969, an oil production platform had a blowout. Thousands of gallons of oil were released into the ocean off of Santa Barbara. The accident had far-reaching effects. As often happens, the whole picture was only available much later. In the following activity you will have a chance to look at the information about the spill as it was made public. Use the articles to answer the numbered questions.

Part I - The Accident

Time 2/14/69

Tragedy in Oil

It looked like a massive, inflamed abscess bursting with reddish-brown pus. The huge bubble of oil and natural gas boiling up from beneath the surface of Santa Barbara Channel at a rate of almost 1,000 gallons an hour spilled across the blue water for eleven days. It finally coated an area of at least 400 square miles and fouled 40 miles of incomparable beach front with acrid, tarlike slime. Time Correspondent Robert Anson, flying over the despoiled sea, found the fumes noxious at 1,000 feet.

1

Anson also found the mood of quiet, elegant Santa Barbara as black as the waves that lapped its coastline. The shores and neat marinas were disaster areas. The town was crowded with weary, worried men—Coast Guardsmen, chemists, geologists, conservationists. Along the defiled beaches, convicts from state conservation camps joined hundreds of oil workers in heaving shovelfuls of oil-soaked sand and straw into waiting trucks.

On the misty horizon, 5½ miles off shore, 100 oil workers struggled desperately on Union Oil Co.'s 150-ft.-high Platform A. beneath which oil was leading steadily from a fissure in the ocean floor. Barges carrying 15,000 barrels of sealant were towed to the platform, where the crew pumped the plasticlike substance down into a 3,500-ft. hole in the ocean's bottom at a rate of 1,500 barrels an hour. For days, capping efforts had been stymied by high seas, and escaping oil had continued to spread out from the long-legged rig at the rate of three miles per hour, cutting a devastaging swath through the water.

3

2

....After getting permission to cut some corners from the U.S. Geological Survey, an arm of the Interior Department that has the responsibility of enforcing federal laws governing drilling. Union Oil went ahead and drilled A-21. Having burrowed down 3,400 ft. below the ocean floor, the riggers then began to retrieve the pipe in order to replace a drill bit. At a point during the withdrawal, the drilling "mud," which is constantly pumped into the well to maintain pressure, became dangerously inadequate for the job. The well blew. An initial attempt to cap the hole was successful, but that led to a tremendous buildup of pressure. The expanding mass widened a fissure, and the released gas and oil bubbled and boiled through the crack and up 700 ft. to the surface. Essentially, when the fateful fissure occurred, Union was operating below regular federal—and far below California—standards.

Newsweek 2/17/69 The Great Blob

The trouble all started two weeks ago with a Union Oil Co. drilling operation 6 miles off the coast of Santa Barbara, an affluent town of 73,000 some 90 miles up the coast from Los Angeles. The drillers had reached down 3,500 feet under the ocean floor when they decided to withdraw their drill pipe to replace its worn bit. This unexpectedly uncorked a pressurized pool of oil and allowed the black subrerranean goo to boil up through the drill shaft, into a vertical fissure and out through the 200-foot-deep ocean floor. Rising to the ocean's surface, the inexorable flow turned into a horrible uncontainable mess.

Time 2/21/69 The Dead Channel

The Dead Channel

The killing sea of oil off Southern California grew ever wider and more elusive. Though the eleven-day leak on Union Oil Company's offshore rig had been successfully plugged, its 800-sq.-mi. slick returned with each tide. And it was fed anew by a residual leak under Platform A that appeared last week.

Part II - The Clean Up

Newsweek 2/17/69

In Washington, President Nixon proclaimed himself in favor of more stringent regulations, and later the White House said he was considering sending Federal troops to help clean up.

Vacuum: Hundreds of men were already busy trying, with only limited success. Inmates from state conservation camps spread straw, talc and pearlite along the beaches to soak up the oil. Farm mulchers on barges spewed hay into the harbor and men in small wooden punts followed, pulling in the oil-laden straw with garden rakes. Pumpers tried to vacuum up concentrations of the oil.

All such measures were only stopgaps at best, however, as long as the oil kept flowing. And only at the weekend, after the oil had been bubbling up for 12 days at 21,000 gallons a day, could immensely relieved Union officials claim to have halted the flow. Huge amounts of a viscous chemical "mud" plus cement forced down the ruptured shaft finally did the trick. There was still all that oil on the water, however, at least 300 square miles of it, and there was no telling quite when Santa Barbara's black plague would end.

Time 2/21/69

Union Oil announced that it would bear the full cost of repairing the mess, and instituted "Operation Sea Sweep." The company sent a huge cleaning contraption into the slick. Powered by tug, the V-shaped strainer——250 ft. across——skims the surface, and deposits oil in a barge. Trouble was, the swells constantly interrupted the devil's labor.

Though detergents and chemicals were used initially at Santa Barbara, by last week the practice had been abandoned. Part of the reason was that the various processes proved ineffective. But in their zeal to restore the beauty of Santa Barbara's beaches——some valued at $2,000 a front foot——crews incurred the ire of conservationists by steam-cleaning the rocks, thereby cooking marine life that had escaped the oil.

4

Newsweek 2/24/69

The company said it would attempt to reduce the pressure, but meantime onshore winds blew the new oil landward, and the sandy beaches and inlets around Santa Barbara were subject to a new, albeit comparatively mild, onslaught. Almost simultaneously, the company launched an enormous, seagoing vacuum cleaner to try to keep ahead of the goo. Two tugs pulled 800-foot sections of pipe that formed a V through concentrations of the oil. At the pipes' vortex a large barge sucked up the oil and transferred it to another barge.

Mess: A thousand men in all were busy in the cleanup operation. The magic cleanser was straw, spread on oily patches of water or sand and raked up and carted away. But hordes of salesmen descended on Santa Barbara peddling such nostrums as Death Valley pumice as cure-alls for the gooey pestilence.

5

Even if no more oil should seep up from the ocean floor, officials estimated it would be three weeks or more before man and nature could eliminate the mess. For the moment, however, at least Santa Barbara's frightened tourist industry reaped an unexpected windfall from the misfortune as thousands of curious visitors flocked to the scene. "Santa Barbara says it's worried about tourism," said Paul DeFalco Jr., regional director of the Federal Water Pollution Control Administration and head of the cleanup operation, "but I'm just waiting for the vendors to start selling ribbons printed with 'We saw the oil slick in Santa Barbara'."

Part III - The Results

Time 2/14/69

Threatened Haven. Sea life and birds suffered a sad fate. Cormorants and grebes dived into the oily swells for fish, most never to surface alive. All along the mucky shoreline, birds lay dead or dying, unable to raise their oil-soaked feathers. Survivors were rushed to one or three centers nearby to be cleaned in a chemical solution, then carefully wrapped to stave off pneumonia and placed in warm pens to recover. Of the more than 500 birds brought in by week's end, two-thirds had survived. The fouled waters threatened thousands of rookeries on the Santa Barbara Islands, haven for the sea elephant, the Guadalupe fur seal (once thought extinct) and the rare sea otter.

6

Newsweek 2/17/69

Stench: When the wind shifted inland early last week, the oil drifted onto Santa Barbara's pearl gray sand beaches, the major attraction of a booming $46 million-a-year tourist industry. A thick sludge that glistened like blackberry jam was deposited by the tides close to the town's $100,000 homes and $2,000-a-front-foot seaside lots. Yachts in Santa Barbara's harbor turned black 2 feet above their water lines where the sludge lapped up against their hulls. Distraught residents watched helplessly as cormorants tried to clean one another's plumage with their beaks, but succeeded only in getting more of the lethal muck in their mouths and eyes. Hundreds of sea birds dropped dead. And everywhere was the pungent stench that wafted miles inland from the sea.

Newsweek 2/21/69

Wherever it shifted, the oil brought ecological disaster to bird and sea life. At Santa Barbara's three treatment centers, 1,400 sea-diving birds had been brought in. Only a third survived. Other shore-line birds, such as curlews, plovers and willets, which feed on sand creatures, had fled the area.

7 The oil and the chemicals that were used to dissolve and distribute the slick were deadly to sea life. Carl Hubbs, marine biology professor emeritus at La Jolla's Scripps Institution, predicted "a complete destruction of life in the intertidal regions along the shore for 20 miles, and considerable destruction for as many as 50 miles." As if in confirmation, the bodies of six seals floated onto Santa Barbara beaches. Autopsies performed on one of three dead dolphins showed that its blowhole had been clogged with oil, causing massive lung hemmorrhages.

8 The Santa Barbara Channel, where the leak occurred, has been one of the best of California's fishing grounds, yielding 27 million lbs. of fish, including mackeral, anchovies and bonita, in 1967. Since the spill, the Fisherman's Cooperative Association of San Pedro has not taken a fish out of the channel. "We haven't even seen one," says General Manager Tony Pisano. Lobster and crab fishermen retrieving their pots from the channel found their catch alive, but completely covered with oil.

Part IV - Politics

Time 2/14/69

9 For Richard Nixon, who has had little time to act on the strong recommendations of his environmental task force, the Santa Barbara disaster was a reminder of the ineffective, 15-year-old laws that rule offshore drilling. Nixon promised to put fresh teeth in federal regulations "so that 10 this kind of incident will not occur again." But his Secretary of the Interior did little to reinforce the President's pledge. Nixon had sent Walter Hickel to the disaster area in a presidential jet. At first, Hickel impressed Santa Barbarans by persuading all oil companies in the area to suspend operations. Then, inexplicably, Hickel reversed himself, only to re-reverse his stand two days later and close the rigs down again. Hickel's ambivalence and his defense of Union Oil infuriated conservationists, who noted that the Secretary had close relations with the oil industry while Governor of Alaska. Nor were the citizens of the oil-soaked town reassured "I have the feeling," said Fred Eissler of the Sierra Club, "that if Hickel walked into Santa Barbara right now, the people would tar and feather him. And God knows, we have plenty of both."

11 The Democrat's Water Quality Improvement bill, which was waylaid during the 90th Congress, was given a much better chance of passage in the wake of the Santa Barbara foul-up. Even the American Petroleum Institute, which had represented the industry in fighting the bill, now gave its blessing. Among other things, the bill would subject ships and installations, such as oil rigs, to fines as high as $5,000 for spillage. Willful violators would be liable for damage up to $15 million. Moreover, rigs would have to meet quality standards of the state.

Newsweek 2/17/69

10 "We are now in the unenviable position of saying we told you so." seethed Frederick Eissler, a local teacher and a director of the Sierra Club. Eissler demanded that the U.S. halt all drilling in the channel. There was an outcry against new Interior Secretary Walter Hickel, though it was Hickel's predecessor, Stewart Udall, who had given the oil companies the go-ahead. Heckel flew in, asked the drillers to stop, let them start again next day—and ordered them to stop again three days later.

Time 2/21/69

9 In Washington, President Nixon ordered his science adviser, Dr. Lee A. DuBridge, to form a team of scientists and engineers in an investigation of the Santa Barbara Disaster. Nixon also told the panel "to produce far more stringent and effective regulations" so that "crises of this kind will not recur."

California's attorney general, meanwhile, was preparing two suits for over $100 million each against the Federal Government and Union Oil for damage to wildlife and the shore line. Private suits, such as the one filed in Santa Barbara Superior Court for over $1 billion, may well be joined with the state action.

Newsweek 2/24/69

11 Some conservationists were also beginning to glimpse a larger consolation in the whole affair. Santa Barbara resident Frederick Eissler, a national director of the Sierra Club and one of the more vocal local critics of offshore drilling, said last week: "We're delighted now that the rest of the country can see us and learn a lesson from what's happening here." There was no telling how profound the lesson might be, but at the very least it seemed likely that a bill to impose stiff penalties on oil companies and ships that spill oil in the U.S.'s offshore waters would pass Congress. Just such a bill was lobbied to death last year.

Part V - Four Months Later

Time 6/13/69

Not So Deadly

In the anguished days immediately following the first great leak from Union Oil Company's well in Santa Barbara Channel, scientists warned that animal and plant life in and around the affected waters might be permanently damaged. In retrospect, their dire predictions seem to have been overstated. A study conducted by a team of university of California researchers discloses that the initial fears were exaggerated. As one researcher says: "The most serious problem is an esthetic one. It just looks terrible."

12 When the well first blew out, the problem was certainly serious. Hundreds of birds died in the sepia goo. Lobsters, clams, mussels, fish and untold other small ocean creatures were destroyed. But where scientists, the press and an outraged public erred was in the assumption that the destruction would continue.

13a Dr. Carl Hubbs, professor emeritus of marine biology at Scripps Institution of Oceanography, stated flatly at the time that the channel "will never be quite natural again." Now, four months later, the channel's ecology seems to have been restored to virtually its natural state—although oil seepage continues to smear city beaches.

13b In making their predictions, some of the scientists harked back to two earlier oil disasters—the wreck of the tanker *Tampico* off Baja California and the rupture of the *Torrey Canyon* off the English coast, both of which devastated marine life. While the *Tampico* carried partially refined and relatively volatile diesel oil, the oil seeping up into Santa Barbara Channel was unrefined crude, which is considerably less lethal. Moreover, the Santa Barbara oil spill was spread over a vast expanse of sea and did not wash up onto the beaches immediately. Much of it lingered on the waves before wind and tide carried it ashore. In the interim, it apparently lost much of its potency. In the case of the *Torrey Canyon*, the real killers were the chemical detergents used to cleanse the sea, which British experts concluded caused as much as 90% of the damage to plant and animal life. In Santa Barbara, nontoxic dispersal agents were used, and only in carefully regulated amounts.

15 While the new report downgrades the damage done to date, it does not say that the channel will escape unscathed. No one knows what the long-range effects on marine life may be as a result of the continuing oil seepage. In any case, it appears that the offensive derricks will be around for decades to come. Last week a presidential panel recommended that drilling on the Union lease site, which has been halted for four months, be resumed. The panel contended that the best way to stop the leak is to exhaust the oil reservoir under Union's platform A—an undertaking that could last 20 years or more.

NUMBERED QUESTIONS

Part I - The Accident

1. a. How many gallons of oil leaked into the water each hour?

   b. For how many days did the well leak?

   c. About how many gallons of oil leaked from the well during this period? (Hint: There are 24 hours in one day).

   d. The Time article from 2/14/69 estimated that the oil spill covered ____________ square miles. The Time article from the next week estimated that the oil spill covered ____________ square miles. Since the well had stopped leaking, how could the same oil have covered more area?

2. a. How deep had the drillers dug before the well began leaking?

   b. What were the drillers doing when the leak occurred?

   c. A fissure is a crack in the earth. What role did a fissure play in the oil leak?

3. What technique did the drillers use to try to stop the leak?

Part II - The Clean-Up

4. As the oil leaked out, many attempts were made to clean up the mess. What were four techniques used to clean up the oil?

   a.

   b.

   c.

   d.

5. What was the immediate impact of the oil spill on the tourist industry?

Part III - The Results

6. a. Which group of animals was the first to suffer from the oil spill?

   b. What was done to try and save these animals?

   c. As of 2/14/69 (Time), about _______________ of those treated had survived. By 2/21/69 (Newsweek) only ______________ survived.

7. What was Carl Hubbs prediction for the marine life in the Santa Barbara area?

8. What effect did the oil spill have on fishermen?

Part IV - Politics

9. What did President Nixon promise to do?

10. How did President Nixon's Secretary of the Interior, Walter Hickel respond to the crises?

11. How did people think the oil spill would affect legislation to protect water quality?

Part V - Four Months Later

12. What was the immediate effect of the oil spill?

13. a. What predictions were made regarding the future of marine life in the Santa Barbara Channel?

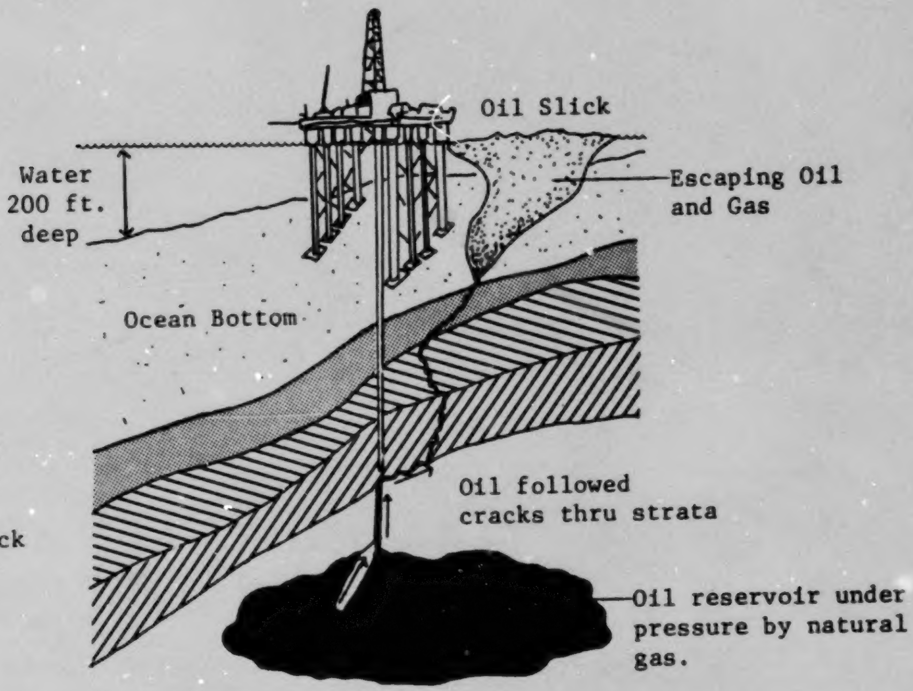
    b. The predictions were made on information learned from the wrecks of the ______________ and the ___________________.

14. The Santa Barbara oil spill was not the disaster it might have been. One reason was that crude oil is more / less dangerous than refined oil. A second reason was that much / little chemical detergent was used to clean up the mess. (Circle the two correct answers).

15. Who knows what the long-range effects of the oil spill on marine life may be?

Part VI - Looking Back

The blowout in the Santa Barbara Channel released 700,000 gallons of oil. This government figure is about three times the oil company estimate. Thirty miles of shore were covered by oil. The drawing below shows what caused the oil to escape.


Oil Slick
Water 200 ft. deep
Escaping Oil and Gas
Ocean Bottom
Oil followed cracks thru strata
Oil reservoir under pressure by natural gas.

What went wrong? A wornout drill was being pulled up when it passed a weak crack or fault. The oil blew out.

16. On the drawing above circle the fissure (cracks) the oil followed from the well to the surface.

Spurred by public reaction, Congress enacted the Water Quality Improvement Act of 1970. This act prohibits (forbids) the discharge of oil "into or upon the navigable waters of the United States, adjoining shorelines, or into or upon the waters of the contiguous zone (12 miles from shoreline). In addition to outlawing oil pollution, the act did other things. Most importantly it provided a program to prevent and control oil spills.

It is unfortunate that it takes a disaster to cause people to safeguard their environment. It is more unfortunate that we forget the damage accidents can cause. During these periods of forgetfulness, we revoke the laws designed to protect the world of water.

17. The Water Quality Improvement Act of 1970 outlaws ____ ____________ and provides a program to __________ and ________________ oil spills.

18. How can we remind people of the importance of environmental protection?

TEACHER BACKGROUND - Oil On Water

"Oil On Water" is a simulation activity designed to give your students insight to the difficulties involved in controlling oil spills. A brief discussion of the effects of oil on the marine ecosystem is found in the Teacher Background section of "December 10". By way of further comment, the common sources of oil pollution follow:

Sources of oil pollution	Millions of tons
non-industrial wastes (mechanics, crankcase, etc.)	2.1
tankers	1.4
industrial (non-refinery)	1.1
natural seeps	0.6
atmospheric fallout	0.4
refineries	0.2
offshore oil platforms	0.1
	5.9 Total

The above list does not differentiate between "point" and "non-point" sources. For example, most crankcase oil comes from many small sources (non-point) rather than from a single source (point). This fact makes the control of pollution from crankcase oil very difficult.

Oils differ greatly. In an attempt to show some of this diversity, the activity employs two types of oil, salad oil and motor oil. As the following list notes, oils also differ greatly in the harm they do to marine environment.

Type of Oil	Ranking (100 is worst)
used crankcase oil	100
new lube oil	98
#2 fuel oil (home heating)	80
Venezuelan oil	47
diesel	41
Kuwaiti oil	35
Alaskan crude	33
Louisiana crude	10

Standard operating procedure for dealing with oil spills involves containment followed by removal of oil from the contained area. A variety of techniques from simple log booms to complex aeration systems have been employed to contain the oil. The systems have met with mixed results. Weather conditions play a major role in the success of the containment operation. Similarly, a variety of techniques have been used to deal with the contained oil. Pumping the oil into empty containers has met with some success as have absorption methods. The danger of widespread detergent use was demonstrated after the wreck of the Torrey Canyon. A large part of the biological degradation from that particular spill was traced to the detergents used to disperse the oil. To date, most techniques have been only marginally successful. Research continues in oil spill technology. Perhaps the technique that holds the most promise for having few inherent environmental dangers involves employing bacteria to breakdown the oil into harmless compounds.

Duplicate the activity pages. One set is recommended per student. This activity is best performed by pairs of students but may be done by individuals or small groups as well. Provide containers for waste oil and for oily cotton, etc. Set a good example by the way you handle the wastes from this activity. While the individual oil spills are not overly time consuming, there are many to do. Caution your students to use their time wisely. You may wish to provide additional materials for your students to use. For example, you might provide sand or dirt since sinking the oil with sand or dirt has been a tactic employed in some spills. As your students perform the activities, circulate through the lab and be available for questions and support. Plan to devote some time to a class discussion of the questions posed in the "Analysis and Interpretation" section.

KEY

1., 2. a.b. Answers depend upon the experimental results.

3. a. The most obvious containment material included in the materials list is the string. The cardboard and styrofoam may also serve to contain the spill.
   b. Booms work best in calm waters. Calm waters come from windless weather.

4. a. The answers will vary depending upon the specific techniques used by your students.
   b. Moving the oil to land does not cause the oil spill to vanish, it just moves it from one place to another. Caution your students to be aware of the "out of sight, out of mind" philosophy so easy to fall into when dealing with this kind of problem.
5. a. The detergent will emulsify the oil spreading it out and changing the physical characteristics of the spill.
   b. While answers will vary, the detergents tend to make absorption techniques less effective because they reduce the viscosity of the oil.
   c. Yes, the fact that detergents kill living things presents some obvious problems when detergents are used to clean up oil spills. The detergents, instead of solving the problem, become the problem. As mentioned above, in the Torrey Canyon spill, the detergents actually caused more damage than the oil.
6. a. Burning puts the oil into the atmosphere as various compounds.
   b. The problems that burning oil might cause are the same as those caused by air pollution (respiratory problems, photo-chemical smog, deterioration of air quality, etc.).
7. The weather and wave action are obvious factors which affect the success of spill clean up in the oceans.
8. a. While answers will vary, the most obvious technique for dealing with oil on beach sands is to scrape off the oil soaked sand and dispose of it (out of sight, out of mind, again!).
   b. Shore animals that can move are likely to be *more* / [✓ *less*] affected by the oil on the beach than non-moving animals. (The correct answer is circled).
9. a. Most of your students will feel that the person or organization that causes the spill should be responsible for cleaning it up.
   b. This second question is included to denote a difference in responsibilities. Most students along with the public as a whole, will feel that the person or organization that caused the spill should pay for cleaning it up. A case can be made, however, that the group that causes the spill should pay but should not be responsible for the clean-up operation. The thought is that a "disinterested" third party might be better able to decide when the spill is cleaned up than a "most interested" first party who

is paying the bill. The subtle distinctions between the two questions are worthy of discussion.

10. It is unlikely that you will get unanimity on the list of priorities. The "right" answers depend upon your perspective. During your discussion of the question, ascertain the reasons behind the choices your students made. Present your list of priorities only after you have discussed the lists of your students.

KEY WORDS

absorption
bacteria
blowout
booms
by-products
containment
data
detergent
estimate
ignited
oil slick
oil spill
recovery
results
simulation
techniques

OIL ON WATER

The unlikely has happened. Thirty miles from shore an oil production platform was pulling up a worn out drill. Suddenly, oil and gas began escaping into the water. Blow out! Before the leak can be stopped, 700,000 gallons of oil are released. What can be done to clean up the spill? In the following activity you will have an opportunity to create an oil spill. You will also have an opportunity to clean up your oil spill.

Materials:

Aluminum pie plate, plastic bowl or similar container
motor oil, used or new
salad oil
cotton balls
spoon
eye dropper
nylon net, piece
nylon hose (stocking), piece
styrofoam, piece
cardboard, piece
string, piece
straw
detergent

Procedure:

1. Obtain an aluminum pie plate or similar container. Place about one inch of water in the plate.
2. Use an eyedropper to place 15 to 20 drops of salad oil on the surface of the water in the dish.
3. The problem you face is the same as that faced by the people of Santa Barbara. How can you clean up the oil with the tools at hand. Select any of the materials available and use it (them) to clean up the oil slick. Use a watch with a second hand to determine the amount of time it takes you to clean up the spill. Use the Data Chart to record your results.
4. Repeat the simulation by adding new salad oil. Try at least three different techniques and materials and record the results.
5. Up to this point you have been using a "light oil". Now perform the same procedures using a heavier oil, in this case motor oil. Record your results in the Data Chart.
6. You have been very lucky. The weather for your oil recovery operations has been fair and calm. Many oil spills occur when the weather is stormy. To simulate rough weather, carefully make waves in your model ocean. You can make waves by gently blowing over the surface or by moving a card through the water. Repeat two of the techniques with heavy oil and rough water. Record your data in the Data Chart.

7. Select the method you feel works best and modify it as follows. After you have added the 15 to 20 drops of heavy oil, add 5 to 10 drops of detergent. Stir the water to mix the oil and detergent. Then proceed to remove the oil/soap mixture with the technique you selected. Record your results in the Data Chart.
8. Clean up your lab station. Place the used oil in the container provided by your teacher. Wash the equipment with detergent and store.

Analysis and Interpretation

1. With which method were you able to most rapidly clean up the oil spill?

2. a. Which method was most effective with light oil?

   b. Was the same method most effective with heavy oil. If not, which method was most effective with the heavy oil?

3. a. The first activities following an oil spill involve attempts to contain the spill. Containment keeps the spill from spreading. Which of the materials provided would help to contain an oil spill?

   b. Ocean spills are often contained by placing booms. A boom is a barrier or "fence" of some type. Floating logs, foam, and rubber tubes have been tried. Under what weather conditions would booms work best?

4. Most of the oil removal techniques which use the materials provided remove the oil by absorption. The oil is picked up (absorbed) on other substances like straw, sawdust, etc. The oil soaked material is then removed from the water.

   a. Which of the techniques you used removed oil by absorption?

   b. Some people say that these techniques simply move the oil spill from the water to the land. What do you suppose they mean?

5. a. What effect did the detergent have on your oil spill?

   b. Did the detergent make your clean-up technique more effective or less effective? Please explain.

   c. Detergents are useful in cleaning because they kill bacteria. Does the fact that detergents kill living things present any problems when detergents are used to clean up oil spills? Please explain.

6. Fire is another technique often used to remove oil spills. The oil spill is ignited and allowed to burn.

   a. Where does the oil from the water go when it is burned?

b. What kind of problems might this cause?

7. What is one factor which affects the cleaning up of oil spills in the ocean?

8. Once the oil reaches the beach other problems occur.

a. What is one technique you might use to remove oil from beach sands?

b. Shore animals that can move are likely to be more / less affected by the oil on the beach than non-moving animals. (Circle the correct answer).

9. a. Who should be responsible for cleaning up the spills?

b. Who should pay for cleaning up the spills?

10. Some bacteria will use oil as their only food source. Ocean scientists would like to be able to "plant" these bacteria in oil spills. For these bacteria to be successful in cleaning up spills, the bacteria have to pass several tests. Some of the tests are listed below. (Rank these tests in order of importance). In the blank next to the test write in the order number. The most important test to consider would be number one, etc.

____cost of the bacteria

____the bacteria will eat the oil quickly

____the bacteria will eat the oil thoroughly

____the bacteria will produce no harmful by-products.

____the bacteria will disappear when their job is done.

DATA CHART

	Material	Time to clean spill	Estimate the % of oil cleaned up	Comments: (eg. messy; left with oily straw, etc.)
LIGHT OIL				
HEAVY OIL				
Heavy Oil and Rough Water				
Heavy Oil plus Detergent				

TEACHER BACKGROUND - Point/Counterpoint

"Point/Counterpoint" provides your students with a forum in which to demonstrate their knowledge gains. The activity involves pairs of students presenting arguments for opposing positions on a controversial issue. Presentations are limited to sixty seconds per student presentation. No time is provided for rebuttal.

Students select their issue and their position on the issue by drawing. Organize the drawing in a manner convenient to you. You may wish to write the positions on slips of paper and place them in a bowl by the class entry. Each student would then pick up one slip as she came into class. You will need to generate a master list from the slip drawing to circumvent the "I forget's." For added drama you may elect not to tell students who their opponents are until it is time for their debates. Some students will draw a position to defend which they do not personally favor. If this is the case, encourage them to play the devil's advocate. Some suggested topics follow:

Offshore Drilling/No More Offshore Drilling
Superports/No More Superports
Supertankers/No Supertankers
Money for More Oil Exploration/Money for Other Sources of Energy
Money for Conservation Measures/Money for Exploration
Used Crankcase Oil Pollution/Offshore Platforms or Tanker Oil Pollution
Nuclear Energy/Oil and Gas Energy

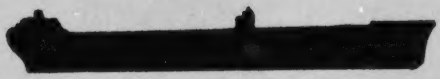
Add and/or substitute additional topics based on current energy issues. Since you will probably have more students than positions, you will need to have more than one presentation on the same issue. In this case, the drawing positions may be set up as follows:

Superport A/No Superport A
Superport B/No Superport B
Offshore Drilling A/No More Offshore Drilling A
Offshore Drilling B/No More Offshore Drilling B
and etc.

Give your students time to prepare their presentations (either in class or out). During the presentations, you should act as timer. You may elect to interject some summary comments but try to avoid monopolizing the discussions. You may also wish to provide blank outline pages so that your students may summarize the arguments of their classmates in preparation for a quiz or other evaluation instrument.

KEY WORDS

concise
exploration
issue
nuclear
offshore drilling
pollution
position
superports
supertankers



POINT/COUNTERPOINT

Superports, offshore drilling, supertankers, oil pollution are all issues of concern for the future. How do you feel about oil energy? In the following activity you will have a chance to express your opinions. You'll also be able to show how the "facts" support your opinions.

Follow the directions of your teacher to draw your issue and position. The position you draw may not be the position you actually support in real life. However you are to support the position you draw as though you have always favored and supported it. Your presentation will be one minute in length. Time will be called after one minute. You will probably want to make an outline of what you want to say. An outline will keep you from leaving out your key points. Your outline may differ from the one given below. You may have more or less points.

Position ____________________
By ____________________

I. ______________________________
  A.
  B.
  C.
II. ______________________________
  A.
  B.
  C.
III. ______________________________
  A.
  B.
  C.

BOATING SKILLS

TEACHER BACKGROUND - December 15

The regular migration of the California gray whale is followed by millions of people. Because it passes close to shore in such populated areas as Southern California, the gray whale has received considerable attention. Many small boat operators earn a substantial income from whale watching tours. "December 15" gives your students a glimpse at this activity while providing an introduction to some concepts dealing with basic boat handling, construction and safety.

There is some concern that whale watchers disturb the whales' communication system and disrupt their migratory behavior. It is clear that certain kinds of watching disturb the whale. Two of the more disruptive techniques are described in the student text question number two. The technique used by the fictious Captain O.L. Salt in the student text appears to have minimal negative affects. We are not certain that there are no ill effects. We must monitor the whale population and their behavior until we can be sure that whale watching is harmless. It would be a shame if we loved the whales to death!

An interesting account of whale watching, albeit humpback whale watching rather than gray, is found in:

Brother Whale - A Pacific Whalewatcher's Log by Roy Nickerson 1977. Chronicle Books, San Francisco. 155 pages.

Duplicate the text pages. One set is recommended per student. This activity is best accomplished by individual students as homework or as an in-class assignment. If your circumstance allows, a whale watching trip for your students is an unforgetable experience. Plan to discuss the text questions as a review of the materials presented in the reading.

KEY

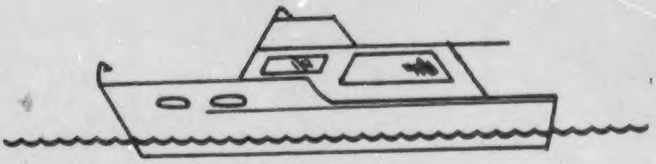
1. The faint cloud is the whale's blow or exhalation. The cloud is actually caused by the rapid expansion of warm, moisture-laden breath in the relatively cool ocean air. Note that the question asks for a supposition on the part of your students. The "right" answer for the question, then, is whatever your students suppose to be the cause.

2. Your students should have circled choice "b" as the method used by Captain Salt. His technique and the technique of the most successful whale watchers involves slow approach from the rear of the animal. The boat is then gently moved closer, then turned away and leaves. All of the manuevers are performed with the motor running at a constant speed at or slightly above the speed of the whale.
3. The circular motion of the whale follows the regular pattern shown by the correctly ordered sequence shown below:

   a. *head and blow hole* b. *back* c. *flukes*
4. The term "whale" is thought to come from Anglo-Saxon, Norwegian, and Dutch terms meaning wheel. The regular, circular motion through the water may have reminded the shore dwelling people of giant wheels turning through the water.
5. The answer will depend upon your geographic location.

KEY WORDS

arches
blow
blow hole
bulges
cascade
flukes
gleam
migration
pattern
rails
reverent
scan
sleek
spout
submarine canyons
surfacing
swirl
techniques
varieties
whale watching

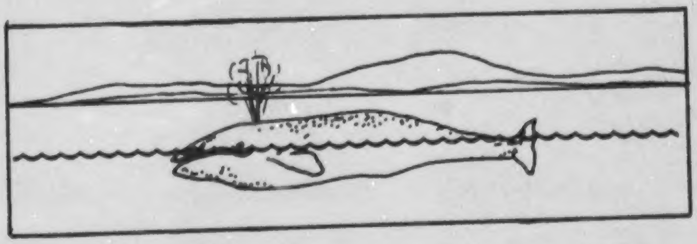


DECEMBER 15

Swimming stronger now, our whale passes south of Santa Barbara. In these Southern California waters, she becomes one of the most watched whales in the world. As the sun appears in the eastern sky, our whale passes the mouth of Santa Monica Bay. She pays little attention to a sleek white boat leaving the dock at Marina Del Rey. Soon the crew on the M/V Sneaker will be paying plenty of attention to our whale.

Captain O.L. Salt turns the Sneaker into deep water. On board, thirty people stand along the rails. The passengers present an interesting picture. Retired couples in hats and sweaters. Middle-aged men and women in Hawaiian shirts and Army jackets. Teen-agers and children exploring the boat's workings.

Captain Salt scans the waters. The morning water is glassy and clear. Captain Salt notices a flashing gleam of light. The water bulges slightly. A faint cloud hangs over the water as the hump disappears. The show is missed by all but O.L.



1. What do you suppose caused the faint cloud seen by Captain Salt?

Captain Salt sets his motor speed and moves toward the activity. Within a few minutes, the Sneaker has found the spot. Several hundred yards ahead, the surface of the water is broken. A distinct spout or "blow" appears. It is followed by a sleek black back. With a silent swirl, the tail flips into the water. Thirty pairs of eyes stare at the swirling water. Captain Salt continues to move slowly closer. His motor running at the same speed. A few seconds later, another spout. A more distinct form appears, closer this time. Thirty hands point at the spot. At the same speed, the Sneaker approaches our whale from the rear. Thirty feet ahead the water bulges. Spray erupts from the dark surfacing body. The grayish-black back arches. With her nose pointed downward, she begins her deep dive. Captain Salt and his crew of whale watchers see her 10 foot wide flukes rise into the air. The water cascades off the trailing edge as the whale disappears from sight. The Sneaker, its engine still running at the same speed, turns away from our whale. The thirty spectators stand in reverent silence. They have seen the whale.

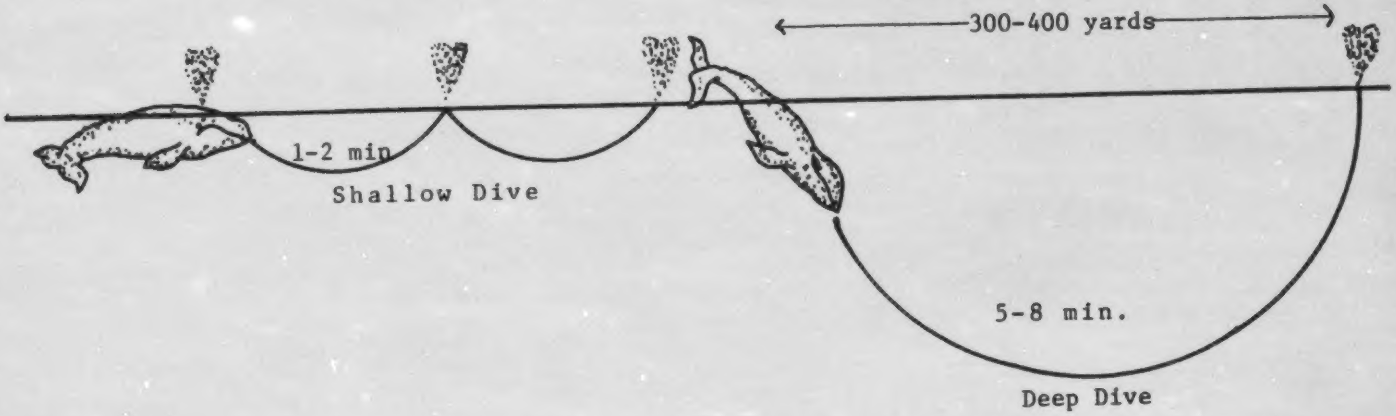
2. Whale watchers come in all varieties. Captain O.L. Salt is among the best. His whale watching method is very effective. It also causes little disturbance to the whales. They are not slowed in their migration. Three techniques for whale watching are listed below. Circle the one used by Captain Salt.

a. "RACING APPROACH TO GET TO THE WHALES QUICKLY, THEN SLOWING DOWN TO STAY WITH THEM. IF THEY MOVE AWAY, RACE OVER TO THEM AGAIN TO GET AS CLOSE AS POSSIBLE."

b. "SLOW APPROACH FROM THE REAR OF THE ANIMALS AT THEIR SPEED. THEN GENTLY MOVE CLOSER, LEAVING THE MOTOR RUN AT A CONSTANT SPEED."

c. "MORE RAPID APPROACH FROM BEHIND THE ANIMALS, WITH SOME RACING OF THE ENGINE TO CATCH THEM QUICKLY. THEN SLOWING TO STAY WITH THE WHALES LONGER."

During the next three hours of whale watching the crew on the Sneaker learn a lot about gray whales. They notice that the pattern of surfacing is always the same. First the head and blow hole appear, then disappear. The back is then exposed. As the back submerges on deep dives, the flukes leave the water.



This circular motion helps explain how the whale got its name. The English term whale is linked to the Norwegian *hwal* and the Dutch *wal*. All three terms mean wheel. The spinning of a wheel and the swimming of the whale looked similar to early peoples.

3. The circular motion of the wale follows a regular pattern. Place the following in their correct order of appearance:

BACK   HEAD and BLOW HOLE   FLUKES

a. ______________ b. ______________ c. ______________

Boat travelers are not the only people who can watch whales. California gray whales pass close enough to land to be easily seen from many areas. Wherever mountains meet the sea, the coastal cliffs are ideal for whale watching. Particulary high cliffs give the viewer a picture similar to what she would see from an airplane. Unfortunately, such areas often are without roads. Where deep water comes close to land, young whales follow submarine canyons to near the beach. The list below gives some recommended areas for observing migrating gray whales.

CANADA: Queen Charlotte Islands (west coast)
Vancouver Island (west coast): Provincial State Park at Long Beach. A few nonmigrating whales are present here the year around.

UNITED STATES:

Washington: Cape Flattery to Cape Alava Olympic National Park, La Push, Queets (whales tarry at mouths of all rivers emptying into the sea).

Oregon: Columbia River, as well as all other river mouths.
Seal Rocks

California: Northern California river mouths
Point Reyes National Sea Shore
Fort Ross State Historic Monument
Point Lobos State Reserve
Monterey/Carmel Area
San Simeon coast along State Highway 1
Morro Bay
Montana do Oro State Park

La Jolla
Cabrillo National Monument San Diego

Baja California: Coronado Islands
Punta Banda (Ensenada)
San Martin Island
Santo Tomas Point
Scammon's Lagoon
Magdalena Bay
Cabo San Lucas

4. How did the whale come to get its name?

Many private boat owners enjoy whale watching. The activities that follow will give you help in finding whales.

Once you've found the whales, you'll need to get out to see them. Other activities will give you a chance to build a boat and to learn some boating safety.

5. From the list above, where is the closest place for you to go and watch gray whales?

TEACHER BACKGROUND - Follow That Whale!

The ability to read and understand a nautical chart is an essential skill for all who work on the water. The chart is an indispensable guide with all the information one needs to safely pilot a boat from point to point (when in sight of reference points) to determine one's position on the water. In conjunction with "Hmmmmm.........Where Did You Say We Were", this activity forms an introduction to navigation and piloting.

Nautical charts contain a wealth of information. The symbols and abbreviations included in the activity represent but a small part of those in use on charts. For a more complete listing of the symbols and a comprehensive treatment of charts and navigation, the following reference is recommended reading:

> Chapman, Charles F. Piloting, Seamanship and Small Boat Handling. Motor Boating and Sailing Book Division, The Hearst Corporation. New York. Latest edition.

The information given on nautical charts is accurate as of the edition date. Any changes in the information since that date are described in "Notice to Mariners" available through the Coast Guard.

There are four types of charts commonly published. Sailing charts (usually on a scale of 1:1,200,000) cover large areas of coastline. They are for offshore navigation. General coast charts (1:400,000 or 1:200,000) are for vessels navigating large areas of the coast. Coast charts (1:80,000) are for navigators entering bays, harbors, or navigated inland waterways. Harbor charts (large scale, for example, 1:20,000) show the most detail and are best suited for local coastal navigation.

Most charts are published by the National Ocean Survey (N.O.S.). This agency publishes chart catalogues which you can use to select the best chart for your needs.

Charts can be purchased at most marinas and marine supply stores. These chart dealers usually have N.O.S. chart catalogues for distribution or at least one copy you can look at when selecting your charts. Chart information is also available from National Ocean Survey, Rockville, Md. 20852.

A good way to get old charts to use as instructional aids for your class is to ask the manager of a marine supply store to save his copies of out-of-date charts. To get his money back for unpurchased charts, he simply tears off a corner of the charts and sends the corners in. Instead of throwing away the rest of the chart, the manager can give it to you for class use. You can also purchase training charts (Chart 1210Tr) from the N.O.S. that are intended for instruction in chart use.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished by individual students or pairs of students as an in-class assignment. Post a variety of nautical charts on the walls of your room. The posted charts are required to answer the introductory questions. Be available to explain the nuances of the charts to your students. Upon completion plan to devote some time to a discussion of the concepts presented and the questions asked in this activity.

KEY

1., 2. Answers will vary depending upon the information found on the charts you have posted in your classroom.

3. a. The degree reading found where the magnetic north line passes through the true compass rose is 348°.

   b. Magnetic north is 12° west of true north.

   c. The compass rose shown above has a variation of *12* ° West.

4. Land areas are usually shown in yellow. The word yellow appears on the KEY CHART which follows this section.

5. a.-c. The structures are correctly circled on the KEY CHART.

6. The degrees of longitude and latitude for Huntington Beach are:

   118 ° longitude

   33° 40 ' latitude

7. a. If your chart were colored, the *deep* / [✓ *shallow*] water would be colored light blue (The correct answer is circled).

   b. The greatest depth (437 fathoms) is circled on the KEY CHART. It is found in the lower left corner
   Record the depth in fathoms *437*, and
   in feet *2622*.

8. The aids to navigation mentioned are circled on the KEY CHART.

9. The note to mariners, which is circled on the KEY CHART, warns people that San Clemente Island is closed to the public.

Analysis and Interpretation:

1. Any number of courses may be drawn between Laguna Beach and Sunset Beach. A typical course is shown on the KEY CHART. The aids to navigation and landmarks for the typical course are shown below:

Start: Laguna Beach

Landmarks

N. Spire

Radio Tower - Corona del Mar

Tower - Costa Mesa

Tank - Costa Mesa

Stacks - Huntington Beach

Tank - Sunset Beach

Aids to Navigation

FlG Bell Buoy - Corona del Mar

Fl Bell Buoy - Costa Mesa

Obstrs R "8HB" Fl Bell Buoy - Huntington Beach

W Or Fl Whis Buoy - Huntinton Beach

EMMY Horn - Huntington Beach

EVA Horn - Huntington Beach

ESTHER Horn - Sunset Beach

End: Sunset Beach

2. The total distance covered in the typical course shown on the KEY CHART is 21.2 nautical miles (at the scale of the chart, 5/16" equals one minute of latitude). Your students' answers will vary depending upon the particular course.

3. The red starboard-hand buoy with a flashing light, bell and radar reflector shown on the chart is off of Costa Mesa. Three landmarks that might be used to help find the location are:

   a. *Tower - Costa Mesa*

   b. *Tank - Costa Mesa*

   c. *Stacks - Huntington Beach*

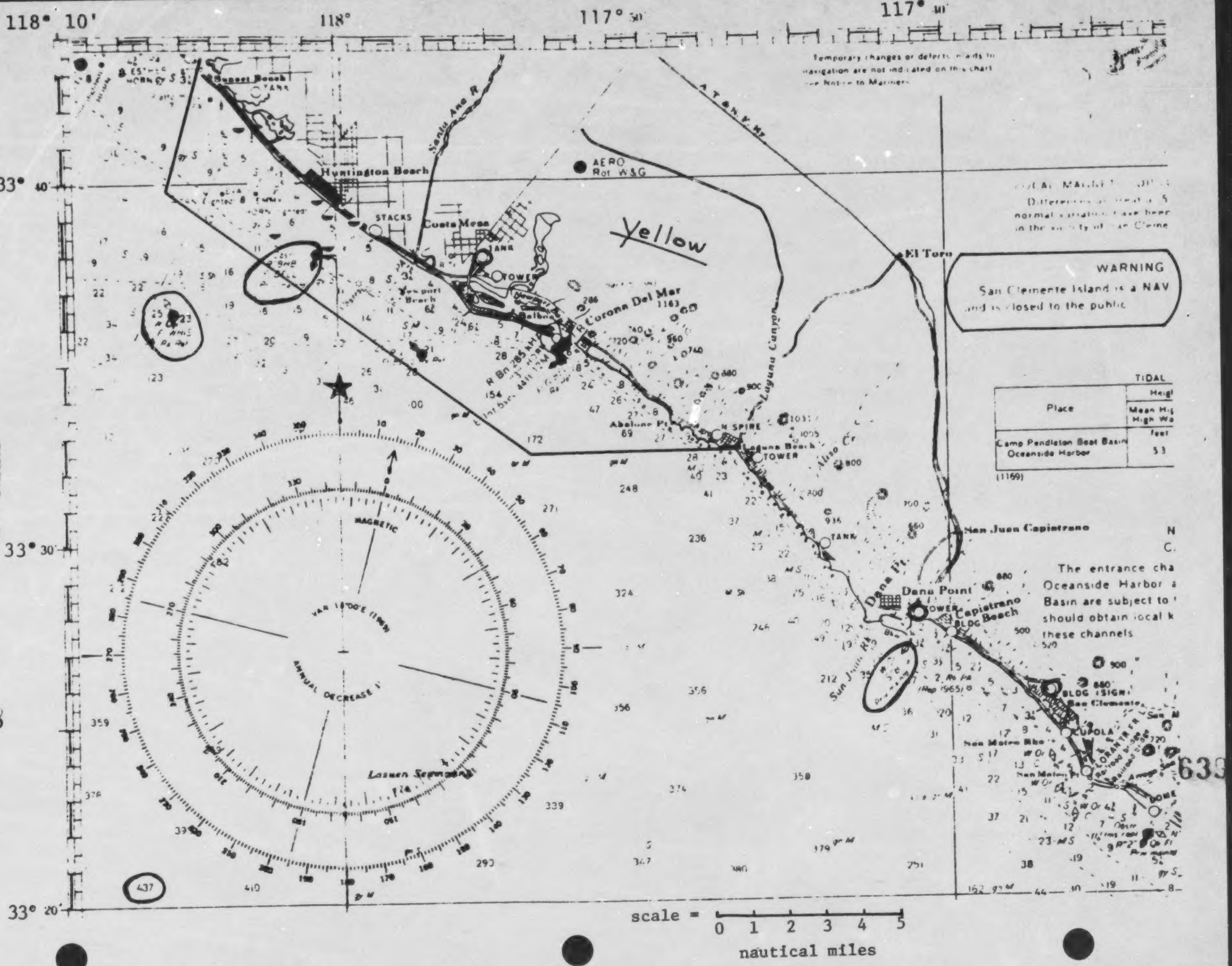
KEY WORDS

accurate
aids to navigation
buoy
chart
compass rose
course
cylinder
degree
denote
distinctive
distort
edition
fathoms
hazards
horizontal
intersect
jagged
landmarks
latitude
longitude
magnetic north pole
margin
Mercator
minutes
nautical charts
nautical mile
navigation
north pole
projection
pursuit
ratio
regulations
revision
scale
seconds
sounding data
symbols
treacherous
variation
venture
vertical

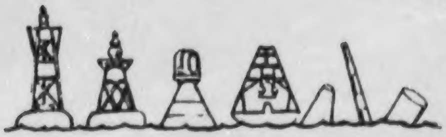
580

KEY CHART

638



118° 10'
118°
117° 50'
117° 40'
33° 40'
33° 30'
33° 20'
Temporary changes or defects in aids to navigation are not indicated on this chart. See Notice to Mariners
Sunset Beach
TANK
Huntington Beach
STACKS
Santa Ana R
Costa Mesa
TANK
TOWER
Newport Beach
Balboa
Corona Del Mar
AERO
Rot W&G
Yellow
El Toro
WARNING
San Clemente Island is a NAV
and is closed to the public
Laguna Canyon
Aliso Cr
Abalone Pt
N SPIRE
Laguna Beach
TOWER
TANK
San Juan Capistrano
Dana Pt
Dana Point
TOWER
Capistrano Beach
BLDG
San Juan Pt
BLDG (SIGN)
San Clemente
CUPOLA
San Mateo Pt
DOME
TIDAL
Place
Camp Pendleton Boat Basin
Oceanside Harbor
Mean High Water
feet
5.3
(1169)
The entrance cha
Oceanside Harbor a
Basin are subject to
should obtain local k
these channels
MAGNETIC
VAR 13°00'E (1965)
ANNUAL DECREASE 1'
Lasuen Seamount
437
639
scale = 0 1 2 3 4 5
nautical miles



FOLLOW THAT WHALE!

So, you want to become a whale watcher. Before you venture out on the ocean, there are a few things you should know. Traveling on the ocean can be treacherous. Beneath the surface of the water lie jagged rocks, waiting to rip holes in the bottom of your boat. The water surface is in constant motion. The water looks the same from place to place. It is very easy to get lost. Nautical charts, road maps of the ocean, can help you plot a safe and accurate course. In the following activity you will have a chance to see some of the types of information found on a chart.

Materials:

- portion of nautical chart
- pencil
- ruler
- posted, complete nautical charts

Procedure:

A nautical chart has several sections. Each section contains valuable information. Most charts can be divided into the title block, the outer margin, the compass rose and the main area of the chart.

Title Block

1. The title block gives you general information about the

chart. Look at one of the complete charts posted in the class and record the following information:

Name of the chart ________________(This tells you the general area covered by the chart).

Projection of the chart ____________ (This is found in the title block directly below the name of the chart. A chart displays the round surface of the earth on a flat piece of paper. There are a variety of ways to show the earth. All of the ways distort the true picture in some way. For charts, the most common projection is the Mercator. A Mercator projection displays the earth's surface as though it was projected onto a narrow cylinder).

Scale of the chart ________________ (The amount of detail a chart shows is indicated by its scale. The scale is the ratio of the size of objects on the chart to the actual size of the same objects. For example, assume the scale is 1:20,000. This means that things will appear 1/10,000 times smaller on the chart than they are in life. An island two kilometers (200,000 centimeters) across will be ten centimeters on the chart.

$$(200{,}000 \text{ cm} \times \frac{1}{20{,}000} = 10 \text{ cm})$$

How big would a five kilometer island appear on the same chart? Complete the equation below.

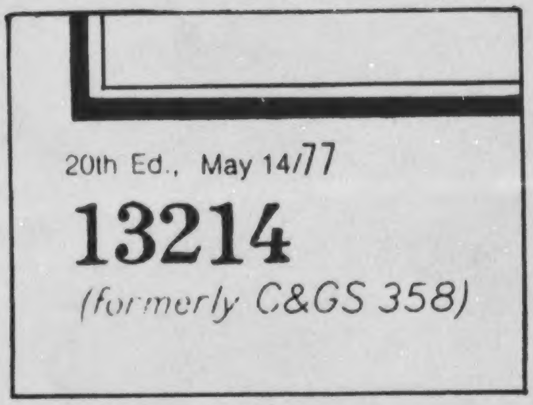
$$(\_\_\_\_\_\_\_\_ \text{ cm} \times \frac{1}{\_\_\_\_\_\_\_\_} = \_\_\_\_\_\_\_\_ \text{ cm})$$

Sounding data. The chart is covered with numbers that tell the depth of the water. The information on depth in the title block tells the unit of depth. (Feet or fathoms).

Soundings in ________________________________

____

The second part of the sounding data tells if the depths were measured at low tide, etc.



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(formerly C&GS 358)

The Outer Margin

2. The outer margin (edges) of the chart also contains important information. Use the chart you examined in number 1 above to record the following information:

Chart Number ______________ (This is the number you would use to reorder the chart. Numbers of the charts that cover the area next to the area of your chart are also given in the margins. In the space below record the numbers of the charts that cover the areas next to your chart.

Chart Number: _______________

Chart Number: _______________

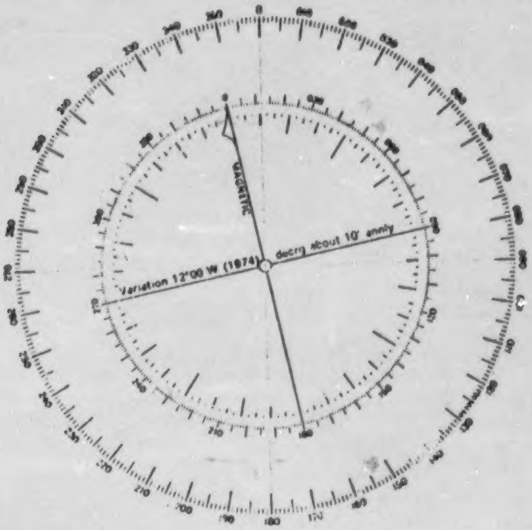
Chart Number: _______________

Chart Number: _______________

Edition of the Chart __________________ (This is the date of the latest revision of the information found on the chart. Any changes in the coastline, or aids to navigation that occurred after the edition date are not on the chart. For this reason, always use the most recent charts).

The Compass Rose

A compass rose is shown below. The rose is used as an aid in determining position on the water. Both the inner and outer ring of the rose are marked off in degrees. The star on the outer ring points toward the true North Pole. The arrow on the inner ring points toward the north magnetic pole.



3. On the compass rose above notice that the magnetic north pole and the true north pole are not the same. Use your ruler to extend the magnetic north line through the true compass rose.

   a. Record the degree reading where the line crosses the true rose: ____________°

   b. On the true rose, 270° is west. Count the number of degrees magnetic north is west of true north (each mark is one degree). Record the number of degrees: ____________°

   c. This difference between magnetic north and true north is called variation. The compass rose shown above has a variation of ___________° west. Notice that this variation is written on the compass rose.

The Main Area of the Chart

The main area of the chart contains the information most important for safe navigation. The chart represents an area of the earth's surface. It tells you how deep the water is and where it is unsafe to travel. It also tells where there are man-made aids to navigation and much more.

4. Obtain a copy of a portion of a navigation chart for southern California. On the other charts posted in your room, notice that land areas are shown in a different color than water areas. On the land area of your portion chart, write in the color used to show land areas.

5. Major towns and distinctive land marks are shown on the chart. The land marks can serve as aids to help boaters locate their position. On your portion chart locate and circle the following:

   a. the water tank in Costa Mesa
   b. the tower at Dana Point
   c. the building with a sign in San Clemente

6. The chart is crisscrossed with a series of vertical and horizontal black lines. The vertical lines represent the imaginery north/south lines of longitude that encircle the earth. The horizontal lines represent the imaginary east/west lines of latitude that encircle the earth. These lines are labeled in degrees, minutes and seconds. (1 degree = 60 minutes; 1 minute = 60 seconds). The symbol for degrees is written °. The symbol for minutes is written '. On your portion chart locate the longitude and latitude lines that intersect (cross) at Huntington Beach. Record the degrees of longitude in the spaces below:

   ____________________° longitude

   ____________________' latitude

7. Boaters must be aware of water depth. The depths are indicated for various points in the water portion of the chart.

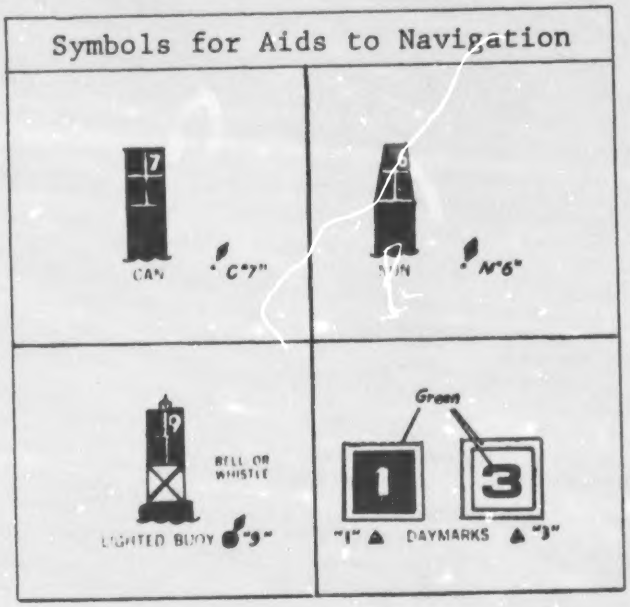
   a. If your chart were colored, the deep / shallow water would be colored light blue. (Circle the correct answer. Hint: look at the charts posted in your classroom.)

b. The depths on your chart are in fathoms. One fathom is equal to six feet. Circle the greatest depth shown on your chart.
Record the depth in fathoms _____________,

and in feet _____________.

8. The Coast Guard and other agencies place and maintain "aids to navigation." These aids include horns, bells, light houses and various kinds of buoys and markers. Buoys are anchored floats.

Some buoys are shown below:


Symbols for Aids to Navigation

7
CAN
C"7"
6
NUN
N"6"
9
BELL OR WHISTLE
LIGHTED BUOY
"9"
Green
1
3
"1"
DAYMARKS
"3"

These aids to navigation are shown on the chart with symbols. Various symbols denote the kind of aid, its location and color. The table below shows the symbols for some common aids to navigation.

SYMBOLS FOR LIGHTS, BUOYS, AND OTHER MARKERS

● ✪	*Position of light*	*F*	*Fixed light*
Lt Ho	*Lighthouse*	*Fl*	*Flashing light*
	Light vessel; lightship	◊ *Priv maintd*	*Private aid to navigation (Buoy) (maintained by private int*
•	*Position of buoy*	◆ *HB*	*Horizontal stripes or bands*
◊ *C*	*Can or Cylindrical buoy*	◊ *VS*	*Vertical stripes*
◊ *N*	*Nun or Conical buoy*	◊ *Chec*	*Checkered*
◊	*Light buoy*	◊ *Diag*	*Diagonal bands*
◊ *BELL*	*Bell buoy*	□ *W*	*White*
◊ *GONG*	*Gong buoy*	■ *B*	*Black*
◊ *WHIS*	*Whistle buoy*	▨ *R*	*Red*
◆ *R "2"* ◊ *R "2"*	*Starboard-hand buoy (entering from sea)*	▒ *Y*	*Yellow*
◆ *"1"*	*Port-hand buoy (entering from seaward)*	▩ *G*	*Green*
◊ *BW*	*Mid-channel buoy (BWVS)*	*Or*	*Orange*
◆ *RB* ◊ *G*	*Obstruction buoy (RBHB or G)*	△ *Bn*	*Daybeacon*
▬ ●	*Mooring buoy (colors of mooring buoys never shown)*	*Ra Ref*	*Radar reflector*
HORN	*Fog horn*	*SIREN*	*Fog siren*
BELL	*Fog bell*	⊙ *R MAST* ⊙ *R TR*	*Radio mast* *Radio tower*
WHIS	*Fog whistle*		

a. Using the table above, locate and circle the following aids to navigation on your worksheet chart:

1. a white and orange light buoy with a flashing light and whistle off of Huntington Beach.

2. a privately maintained red and black horizontal banded obstruction buoy with flashing light and bell near Huntington Beach.

3. a white and orange privately maintained buoy marking the entrance to the breakwater at Dana Point.

9. The charts provide symbols for hazards such as submerged rocks. The type of materials which make up the bottom (sand, mud, etc.) are also shown on the charts. Notes of special interest are included on many charts. For example, the note below describes regulations for areas where submarines travel underwater.

> *Boundary limits of Submerged Submarine Operating Areas are shown by a solid magenta line. As submarines may be submerged in these areas, vessels should proceed with caution. During torpedo practice firing, all vessels are cautioned to keep well clear of Naval Target Vessels flying a large red flag at the highest masthead.*

A portion of a note involving a Naval Reserve on San Clemente Island is included near the right edge of your chart. Circle the note.

What does the note warn people about?

Analysis and Interpretation:

1. As captain of the Beluga you are sailing out of Laguna Beach bound for Sunset Beach. Use a pencil and ruler to draw your course on your chart. In the space below list all land marks you might use for navigation. Also list all aids to navigation as you pass on your way.

START: Laguna Beach

Landmarks	Aids to Navigation

FINISH: Sunset Beach

2. On your chart every minute of latitude equals one nautical mile. For example the distance from 117° 40' to 117° 50' is ten nautical miles. Use your ruler to estimate the total distance you will have covered from Laguna Beach to Sunset Beach.

3. In your cautious pursuit of a gray whale you find yourself near a red starboard-hand buoy with a flashing light, bell and radar reflector. What are three landmarks you might use to help find your location?

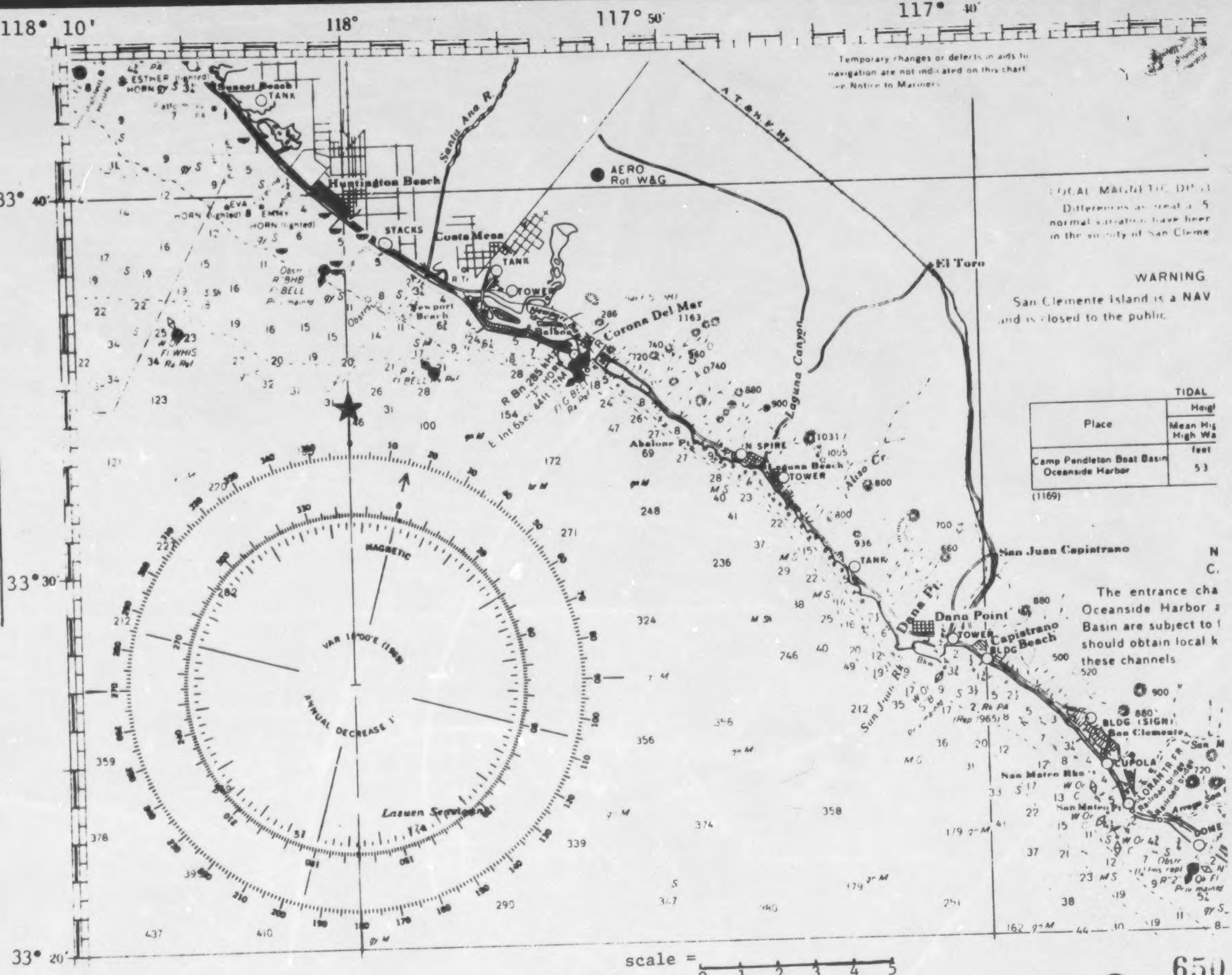
   a.

   b.

   c.

590

NAUTICAL CHART


118° 10'
118°
117° 50'
117° 40'
33° 40'
33° 30'
33° 20'
Temporary changes or defects in aids to navigation are not indicated on this chart See Notice to Mariners
Sunset Beach
TANK
ESTHER (lighted) HORN
Santa Ana R.
A T & S F Ry
Huntington Beach
AERO Rot W&G
EVA
EMMY
HORN (lighted)
STACKS
Costa Mesa
TANK
TOWER
Newport Beach
Balboa
Corona Del Mar
R Bn 285 MH
FI BELL
Laguna Canyon
El Toro
LOCAL MAGNETIC DIS
Differences as great a 5
normal variation have been
in the vicinity of San Cleme
WARNING
San Clemente Island is a NAV
and is closed to the public
Abalone Pt
N SPIRE
Laguna Beach
TOWER
Aliso Cr
TANK
San Juan Capistrano
Dana Pt
Dana Point
TOWER
Capistrano Beach
BLDG
San Juan Rk
BLDG (SIGN)
San Clemente
CUPOLA
San Mateo Rk
San Mateo Pt
DOME
MAGNETIC
VAR 13°00'E (1965)
ANNUAL DECREASE 1'
Lasuen Seamount
TIDAL
Place
Height
Mean Higher High Water
feet
Camp Pendleton Boat Basin
Oceanside Harbor
5.3
(1169)
The entrance cha
Oceanside Harbor a
Basin are subject to
should obtain local k
these channels

scale = 0 1 2 3 4 5

nautical miles

640

650

TEACHER BACKGROUND - Hmmmm.....Where Did You Say We Were?

Most activities on the water, from whale watching to oceanographic sampling, require exact knowledge of the position of the boat. The knowledge gained from reading nautical charts is helpful in establishing the general location of the boat. To determine the precise position, the technique of triangulation is the simplest method to use, providing fixed reference points are in sight. Position determination by triangulation is a basic oceanographic procedure that should be learned by any one who spends time working on the ocean.

Triangulation is also useful for some land-based activities, especially those involving transects. If you have an accurate map of your school grounds, it is possible to give your students some first-hand practice with the mechanics of triangulation. "Hmmmm....Where Did You Say We Were?" provides the introduction to triangulation needed for such an activity.

Successful triangulation depends upon the ability to read a chart, mastered in "Follow That Whale!," and the visibility of fixed reference points. Boats out of sight of fixed reference points determine position by radar, sextant, or by electronic means.

Magnetic compasses are subject to two types of error: variation and deviation. Variation is the angle between the lines of magnetic force (magnetic meridian) and the lines pointing toward the geographic north pole (geographic meridian). It is designated as east or west of the geographic meridian.

Variation is not the same from place to place for two reasons. First the earth's magnetic field is not uniform. Second, the angle between the geographic and magnetic poles changes depending on the distance from the poles. At any one location, however, variation is relatively constant. (Most locations experience a very small annual rate of change.)

The compass rose on a chart displays variation both graphically and numerically. The outer ring of the rose shows directions in terms of true (geographic) north. The inner ring shows directions in terms of magnetic north. The difference between headings on the two rings is the variation for that area. The variation and the annual rate of change are also written in the center of the rose.

Most charts have more than one compass rose. This is because variation may change even within the relatively small areas shown on nautical charts. You should always use the rose nearest your location.

Deviation is a source of error due to the influence of nearby magnetic or metallic objects on the readings of a compass. Unlike variation, deviation does not change with geographical position, though it will change if the compass is moved to a new location on the boat or if an object, such as a portable radio, is placed near the compass. Deviation is not the same for all points of the compass, so many boat operators record the compass deviations at various points of the compass in a deviation table. The deviations are determined by pointing the compass at known magnetic headings and comparing these with the compass readings.

For more information on using a compass, correcting compass errors, and making conversions between true bearing, magnetic bearings, and compass bearings the following reference is recommended reading.

Chapman, Charles F. Piloting, Seamanship and Small Boat Handling. Motor Boating and Sailing Book Division, The Hearst Corporation. New York. Latest edition.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished by individual students or by pairs of students as an in-class assignment. If you do not have parallel rulers, the pattern which follows the student section provides an inexpensive way to make your own. It is best if you have your students make the parallel rulers before you begin the activity. Since the standard hole punch makes holes larger than the legs of the round head fastener, the two rulers need to be gently pulled apart as they are used to keep them parallel. As your students perform the activity, circulate through the lab area to be sure that the rulers are used correctly. A class demonstration prior to embarking on the activity, can save a myriad of later individual instructions. Allow time for a summary discussion in which you provide the correct answers to the questions posed in the student activity.

KEY

The correct position for the boat described in the procedure is shown on the KEY CHART which follows this section. The longitude and latitude for the boat are:

117° 44' longitude

33° 21' 40" latitude

Analysis and Interpretation:

1. The correct location is shown on the KEY CHART. The exact longitude and latitude are:

   117° 48' 25" longitude

   33° 25' latitude

2. The correct location and bearings are shown on the KEY CHART. The compass bearings are recorded in the space below:
   a. Tank at Sunset Beach: 5°
   b. Stacks between Costa Mesa and Huntington Beach: 53°

3. The precise answers to questions C through E depend upon the course drawn by your students. The answers given below are for the typical course found in the KEY CHART for "Follow That Whale!."
   c. Bearing of first leg of course: 75°
   d. Bearing for second leg of course: 290°
   Bearing for third leg of course: 0°
   e. The distances for the course legs are:
   First leg 5.4 nautical miles.
   Second leg 12.2 nautical miles.
   Third leg 3.6 nautical miles.

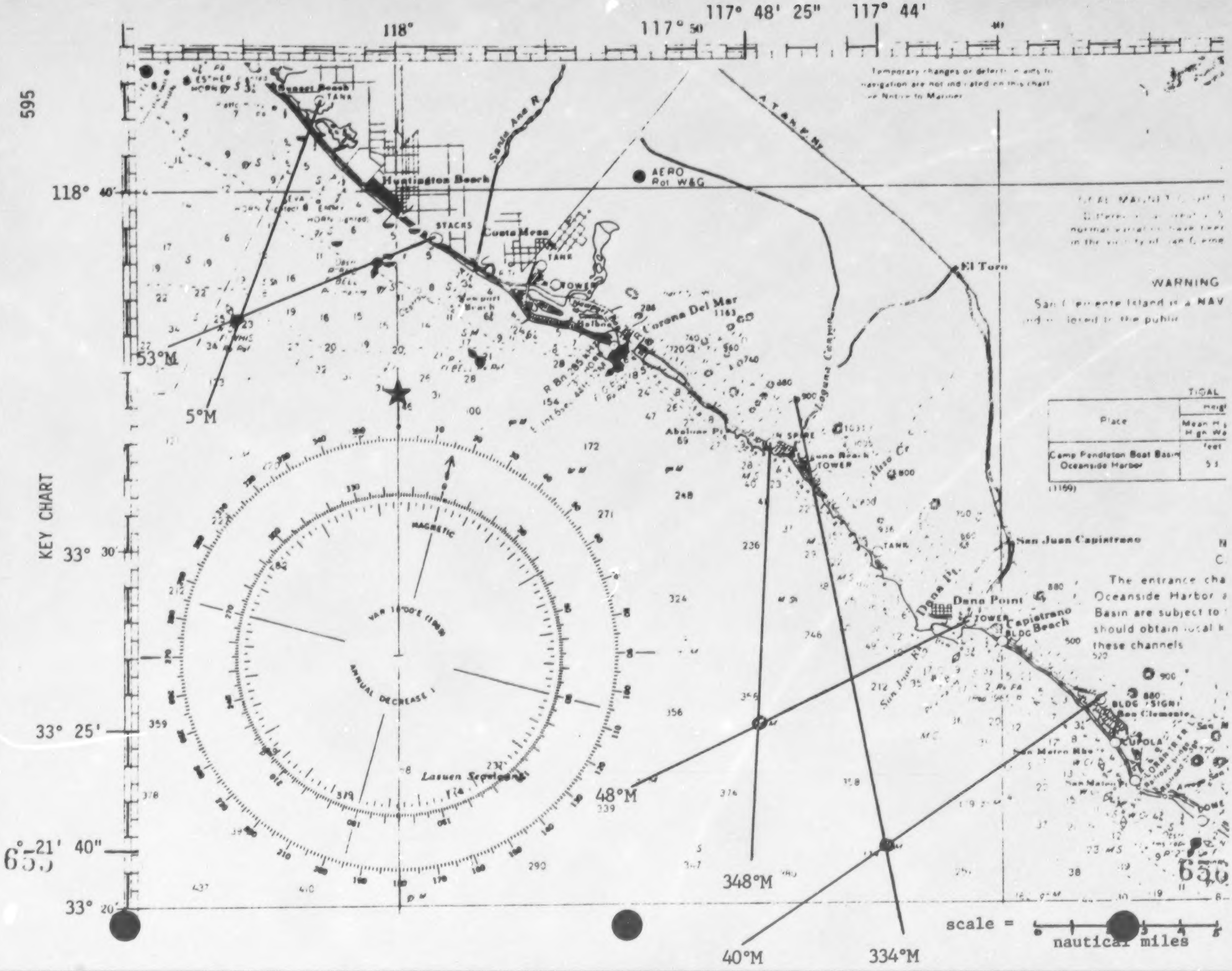
4. This question is included to remind your students that triangulation is only useful under a finite set of circumstances. Radar or other electronic devices are the standard methods for determining position in the fog. It is possible to use a small transistor radio as an aid to position location. The antennas on such radios are highly directional. With the aid of a chart and the radio, it is possible to locate

position by triangulation of marked radio station towers. This is also a good point to stress that watching weather reports to avoid getting caught in the fog is the best course to follow.

KEY WORDS

angle
bearings
buoy
coastal
compass
compass bearings
compass rose
convert
course legs
degree
destination
equivalent
fixed reference points
guideposts
latitude
longitude
magnetic compass
migrating
nautical charts
navigate
parallel rulers
plotting a course
position
relative
scales
taken bearings
triangulation

KEY CHART


118°
117° 50
117° 48' 25"
117° 44'
118° 40'
33° 30'
33° 25'
33° 20'
6°-21' 40"
655
656
Huntington Beach
Costa Mesa
Newport Beach
Balboa
Corona Del Mar
AERO Rot W&G
El Toro
San Juan Capistrano
Laguna Beach
Dana Point
Capistrano Beach
San Clemente
San Mateo Pt.
Santa Ana R
Aliso Cr
STACKS
TOWER
TANK
CUPOLA
MAGNETIC
ANNUAL DECREASE
Lasuen Seaknoll
WARNING
The entrance cha
Oceanside Harbor a
Basin are subject to
should obtain local k
these channels
TIDAL
Place
Camp Pendleton Boat Basin
Oceanside Harbor
Temporary changes or defects in aids to navigation are not indicated on this chart. See Notice to Mariners.
53°M
5°M
48°M
348°M
40°M
334°M
scale =
0
1
2
3
4
5
nautical miles

N
NW
NE
W
E
SW
SE
S

HMMMM....WHERE DID YOU SAY WE WERE?

On land it is usually easy to figure out exactly where you are. Since roads and buildings are shown on maps, you can find your location relative to them. Finding your location on the ocean is more difficult. Out of sight of land, mariners use the stars, radio, radar and even satellites as guideposts. Most whale watchers sail in coastal waters. Near shore, aids to navigation are generally in sight. In "Follow That Whale!" you learned to read nautical charts. Armed with this new found knowledge, you will learn to navigate using visible, fixed reference points.

The technique you will be using is called triangulation. Several fixed reference points are sighted with a compass. Lines are then plotted on a nautical chart using these compass bearings. Your position is the point where the lines cross.

Materials:

portion of nautical chart from "Follow That Whale!"
pencil
parallel rulers or medium cardboard,
scissors
hole punch
4 round-head paper fasteners

Procedure:

You have been watching migrating gray whales since early in the morning. You are now ready to head for home.

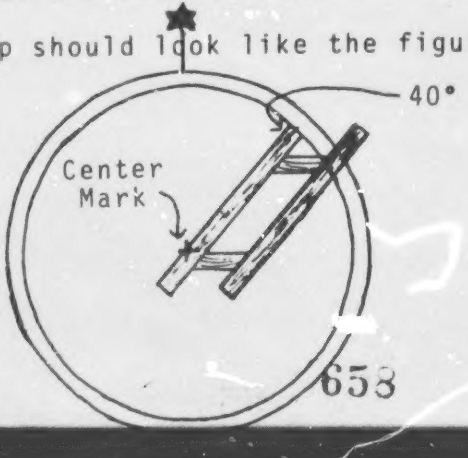
But first, you have to find out where you are. You have taken bearings using a hand held compass. ("Taken bearings" means that you held your compass in one hand, pointed it at a fixed object and read the degrees.) The bearings and their fixed objects are listed below:

Laguna Beach tower: 334°

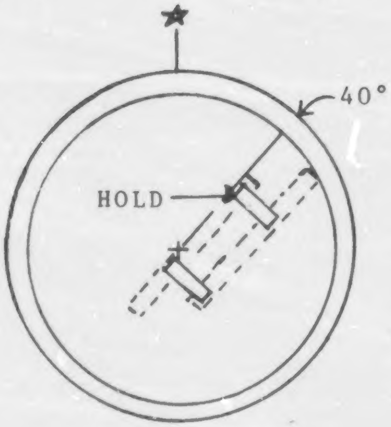
San Clemente Building (Sign): 40°

Follow the steps below to find your position.

1. Locate the compass rose on your chart. It has two scales. The star on the outer ring represents a reading of true north. The arrow on the inner ring points to magnetic north. Since your readings were made on a magnetic compass, use the inner ring.
2. Find the two compass bearings given above on the inner ring of the compass rose. Make a pencil mark on the compass rose for each bearing.
3. Obtain a parallel ruler. (If you don't have a parallel ruler, you can make one using the pattern that follows this activity.)
4. Place one edge of the parallel rulers on the compass rose, lining it up with the center (marked with a +) of the rose and one of the bearings. Your set-up should look like the figure below.

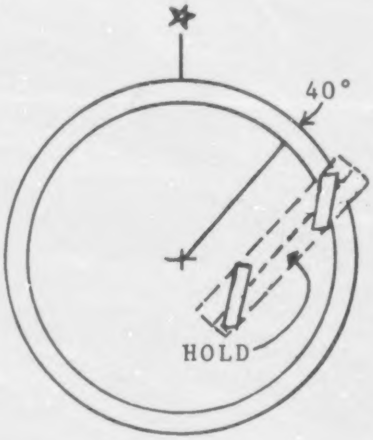


5. The rulers are now set for that bearing and may be carefully "walked" to the reference point (San Clemente Building (Sign)). To walk the rulers, hold the ruler on the center mark firmly in place. Move the other ruler toward the reference point. Then hold the ruler you moved firmly in place and move the other ruler up to it. By repeating this step you can "walk" across the chart while still maintaining the correct compass bearing. The drawing below shows you how.



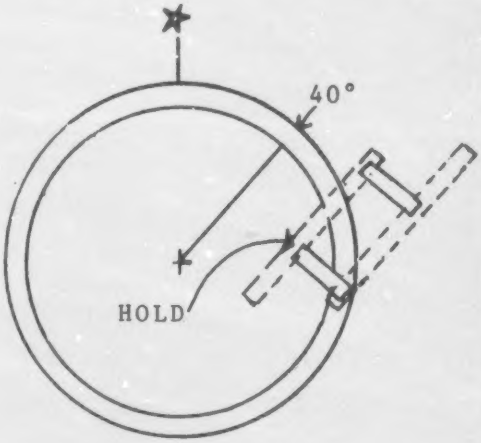
1

"Step Apart"



2

"Step Together



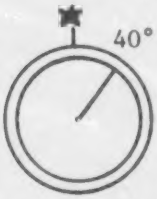
3

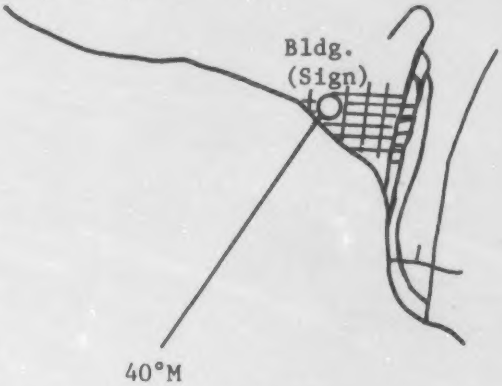
"Step Apart"

Always hold one ruler in place. If they slip, you must start over again.

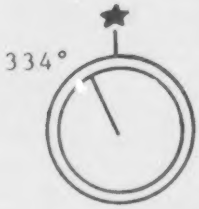
6. When the ruler is lined up with the reference point, draw a line from the object back toward the position of the boat. This line is equivalent to the sighting

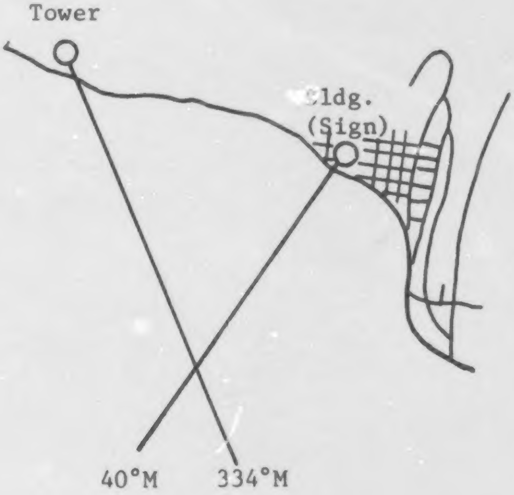
taken with the compass. It passes through the object at the same angle to magnetic north as the compass reading. The position of the boat must be somewhere along this line. Your chart should look similar to the drawing below.





7. Repeat steps 5 and 6 for the second compass bearing. Since the boat must be located on both of the lines, the exact position is the point where the lines cross. Your chart should now look like the one below.





8. The longitude and latitude of this point can be determined by referring to the scales that run along the edges of the chart. In the space below, RECORD the exact longitude and latitude of the boat.

_____________ longitude

_____________ latitude

Analysis and Interpretation:

The first two problems will give you a chance to sharpen your triangulation skills. They use the same chart with which you have been working.

1. You are out on the water somewhere in the area on the chart. You take two compass bearings:

   a. N. Spire at Laguna Beach: 348°

   b. Dana Point tower: 43°

   Plot your location on the chart and then, record the exact longitude and latitude in the spaces below.

   _______________ longitude

   _______________ latitude

2. You have just spent a profitable day watching whales. You are at the white and orange whistle buoy off of Huntington Beach.

   a. What is the compass bearing from where you are to the tank at Sunset Beach? Record the bearing in the space below.

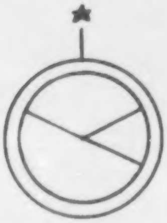
      Tank at Sunset Beach: _________

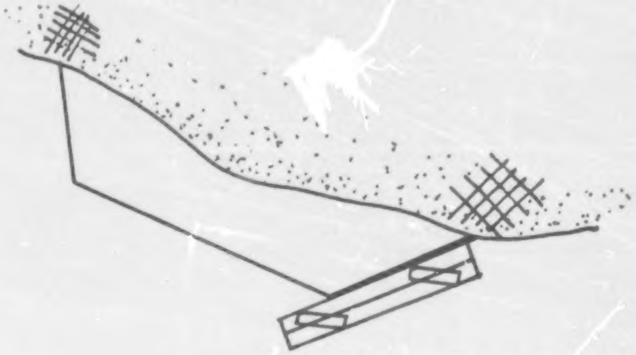
   b. What is the compass bearing from there to the stacks between Costa Mesa and Huntington Beach? Record the bearing in the space below.

      Stacks between Costa Mesa and Huntington Beach: _____________

3. Triangulation can easily be applied to plotting a course on a chart. A course is simply a line drawn on a chart between where you are and where you are going. For example, if you were watching whales you might draw a course from Laguna Beach to Sunset Beach. After you have drawn the course, you can plot it by doing the following:

   a. Line up one edge of the parallel rulers with your first leg (straight section) of the course from Laguna Beach. Your set-up should look something like the picture below.





   b. Walk the rulers over to the compass rose.

   c. Line the edge of the ruler up with the center of the rose. The ruler should now cross the inner (magnetic) ring of the rose at two points. Read the bearing, in degrees, under the edge of the ruler that is in the same direction as the destination point. This is the heading on your boat's compass you must follow for the first portion of the trip. Record the bearing on the course line and in the space below.

      First leg of course ______________°

   d. Repeat steps (a) through (c) for the other legs of your course.

      Second leg __________°

      Third leg ___________°

   e. Next determine how far you must travel on each leg of your course. This is easy to do. Measure the length of line for each course leg. Convert (change) the lengths to nautical miles using the latitude scale. (Remember each minute of latitude equals one nautical mile). Record the distances below.

Distances:

First leg ______________ nautical miles

Second leg ______________ nautical miles

Third leg ______________ nautical miles

4. Now you're in trouble. The fog has suddenly rolled in. You cannot see any reference points. How can you determine your position?

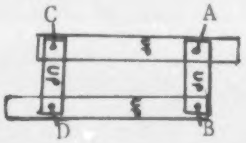
PARALLEL RULERS

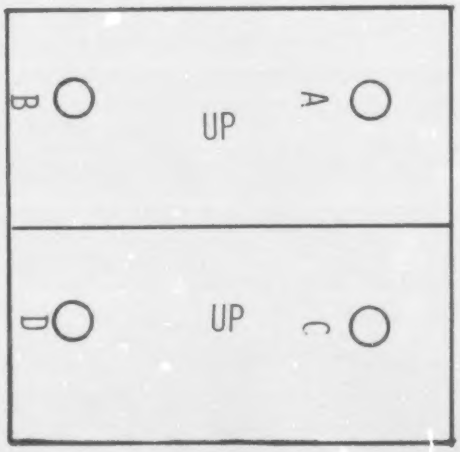
Parallel rulers are a useful navigation tool. You can make your own using this pattern. You will need:

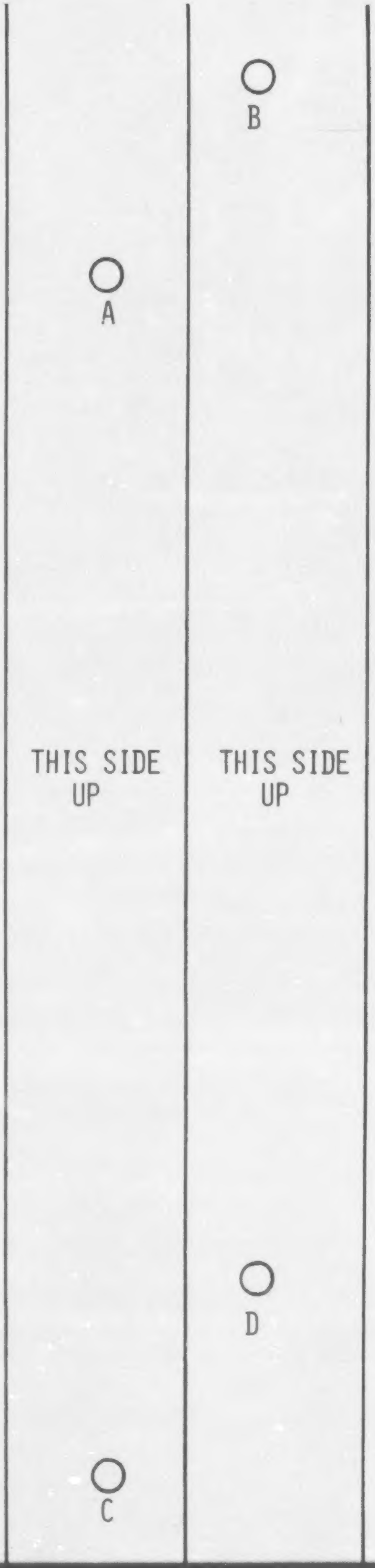
- this pattern
- medium cardboard, posterboard, or railroad board
- 4 round head fasteners
- scissors
- hole punch

Directions:

1. Mark all pattern pieces on medium cardboard. Be sure to include the "UP"s and letters.
2. Cut out the four pieces.
3. Punch out the eight marked holes.
4. Assemble the parallel rulers by placing a round head fastener through each pair of holes (A-A, B-B, etc.)
5. Your finished product should look something like the picture below.







TEACHER BACKGROUND - Whazzat?

Boating has a large and complex vocabulary best learned by use. "Whazzat?" provides an introduction to some of the more common boating terms. The real learning of the terminology can only be accomplished through repetitive use. Incorporate the terms into your vocabulary and use them with your class. The terms are used and thereby reinforced in the boat modeling and building activities which follow "Whazzat?".

For your convenience a glossary of nautical terms is included at the end of this Teacher Background. You may wish to devise additional vocabulary. You can easily create puzzles, acrostics, word puzzles, etc. which will effectively reinforce the vocabulary.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished by individual students as a homework assignment or in-class assignment. Some of your students may find the directions easier to comprehend if you provide a concrete example by completing the first statement. Although this activity is largely self-correcting, your students will benefit from a brief review in which you provide the correct answers to the statements and show the correctly completed dot-to-dot drawing.

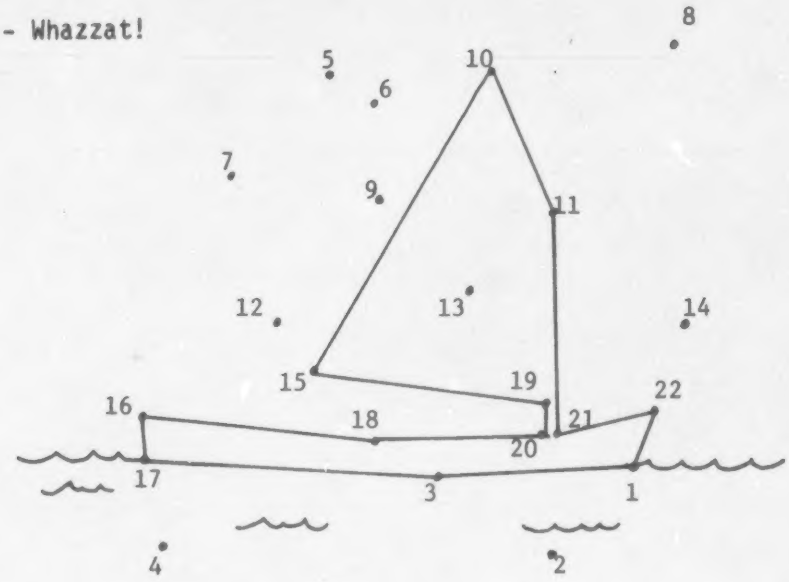
KEY

A correctly completed dot-to-dot is followed by a copy of the question statements in which the correct answers are circled.

KEY WORDS

The key words are found defined in the margin of the first page of the student activity.

KEY - Whazzat!



A. Captain Flash walked back and forth along the bail (1-2) / [✓ gunwale (1-3)].

B. He was mad. His ship, the *Albatross*, was [✓ aground (15-19)] / aft (11-14).

C. "When I find the sailor that put us here, I'll dunk him in the [✓ bilge (10-11)] / keel (9-10)."

D. Sailor Sam was nervous. He had misread the capsize (14-22) / [✓ compass (1-22)]

E. Sam didn't know port from fore (5-7) / [✓ starboard (16-18)].

F. If the Captain found out, Sam would be tied with a [✓ line (3-17)] / oar (12-15).

G. Then he'd be thrown over the [✓ stern (19-20)] / bearing (2-4) and pulled along.

H. Sam crawled forward. In the course (12-15) / [✓ bow (10-15)] he'd be safe.

I. "Aha!," yelled Captain Flash. He grabbed Bill and threw him over the draft (15-16) / [✓ stern (16-17)]

J. Poor Bill was now the ship's [✓ anchor (11-21)] / beam (11-13).

K. No longer could Bill go helm (6-10) / [✓ below (18-20)] decks for comfort.

L. No longer could Bill set on his favorite [✓ thwart (21-22)] / transom (8-14). Justice at sea was harsh and swift.

WHAZZAT?

Nautical charts and triangulation will help you find your position. They will also help you find the position of the gray whale you are watching. You are almost ready to go to sea. But first, you need to learn the proper terms for the parts of your boat. Why? For one thing, you don't want to look like a fool. You want to look like someone who is truly interested in boating. There is another more important reason. In an emergency, valuable time may be saved when correct terms are used for needed tools and action.

Directions:

Each statement below may be correctly completed by one of the two choices given.

There are two numbers after each choice The numbers refer to the dot-to-dot drawing above. Use a pencil line to connect the two numbers that follow each choice you make. Connecting the numbers following the correct choices makes a drawing of a boat. If your connect-the-dot drawing doesn't make sense, neither do your answers to the questions! Use the definitions down the side of the page for help.

Nautical Terms

AFT - Describing the after section of a vessel, or things to the rear of amidship and toward the stern.

AGROUND - Sticking to bottom.

AMIDSHIP - Describing the mid-section of a vessel, either with reference to length or width.

ANCHOR - A forging or casting shaped to grip the sea bottom and, by means of a cable or rope, hold a boat in a desired position.

BAIL - To remove water from a boat by pump or bailer.

BEAM - Imaginary line amidship at right angles to keel of vessel. Also vessel's width amidship.

BEARING - The direction or point of the compass in which an object is seen.

BELOW - Beneath, or under, the deck. One goes below when going down into the cabin.

BILGE - The lower internal part of a boat's hull, adjacent to the keel.

BOW - The forward part or front of the boat.

BUOY - A floating, anchored navigational aid.

CAPSIZE - To turn over.

COMPASS - The instrument which shows the course of a vessel.

COURSE - The point of the compass toward which the boat is being steered.

DRAFT - The depth of the vessel below the water line, measured vertically to the lowest part of the hull.

FORE - Used to distinguish the forward part of a boat or things forward of amidships. It is the opposite of aft or after.

GUNWALE - The upper edge of a boat's side. (Pronounced gun-nel.)

HELM - The wheel or tiller by which a ship is steered.

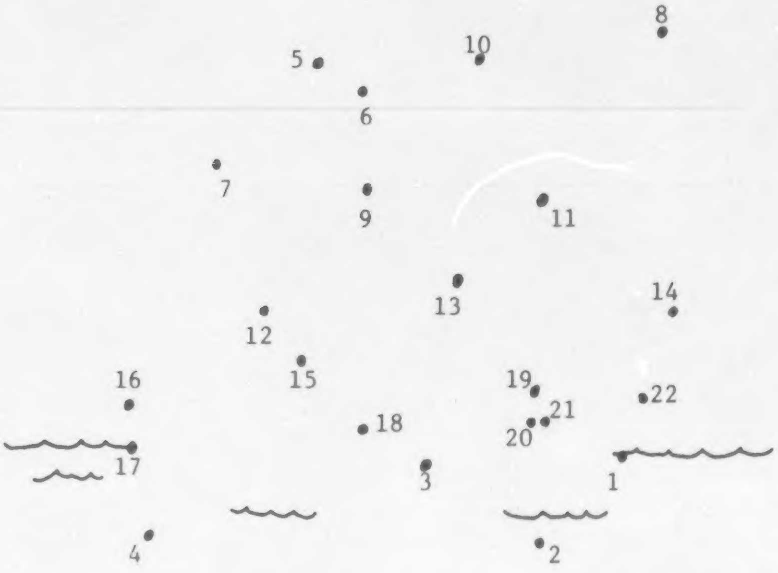
HULL - The body of a boat.

KEEL - A permanently positioned, principal fore-and-aft backbone member of a boat's hull used for stability and/or ballast.

LINE - Rope that is aboard or around a boat.

MAST - A spar set upright to support rigging and sails.

OAR - A long wooden instrument with a flat blade at one end, used for propelling boats.



PORT - The left side of a boat when you are facing toward the bow, also a destination.

RIB - An athwartship frame on a boat.

STARBOARD - The right side of a boat when you are facing toward the bow.

STEM - The upright post or bar of the bow.

STERN - The after end or back of a boat.

STOW - To pack the cargo.

THWART - A seat or structural member extending across a boat, from side to side.

TRANSOM - The planking which forms the after end of a small square-stern boat. (Outboard motors are usually attached to transom.)

A. Captain Flash walked back and forth along the bail (1-2) / gunwale (1-3).

B. He was mad. His ship, the Albatross, was aground (15-19) / aft (11-14).

C. "When I find the sailor that put us here, I'll dunk him in the bilge (10-11) / keel (9-10)."

D. Sailor Sam was nervous. He had misread the capsize (14-22) / compass (1-22).

E. Sam didn't know port from fore (5-7) / starboard (16-18).

F. If the Captain found out, Sam would be tied with a line (3-17) / oar (12-15).

G. Then he'd be thrown over the stern (19-20) / bearing (2-4) and pulled along.

H. Sam crawled forward. In the course (12-15) / bow (10-15) he'd be safe.

I. "Aha!," yelled Captain Flash. He grabbed Sam and threw him over the draft (15-16) / stern (16-17).

J. Poor Sam was now the ship's anchor (11-21) / beam (11-13).

K. No longer could Sam go helm (6-10) / below (18-20) decks for comfort.

L. No longer could Sam set on his favorite thwart (21-22) / transom (8-14). Justice at sea was harsh and swift.

TEACHER BACKGROUND - Boatin'

Why do boats float? "Boatin'" is designed to provide your students with a chance to answer this question. The twelve activities which follow are based on materials originally appearing in the Elementary Science Study booklet Clay Boats (Educational Services Incorporated, Watertown, MA, 1966, Developmental Teaching Edition.)

Any object placed on the water's surface will sink just far enough to move aside - or displace - a weight of water equal to that of the object. If the object is dense, like a block of clay, it will sink. A boat's clay hull will float, however, since the clay is not concentrated in a lump, but encloses a volume of air that, even combined with the weight of the clay, weighs less than an equal volume of water. The activity cards allow your students to derive the essential components of this law of displacement.

The clay boat activities are fun. They also provide your students with opportunities to think, plan, experiment and wonder. These activities provide an opportunity for inquiry and inductive learning.

The activity pages are designed to be made into task cards. After duplication cut the pages in half. You may wish to duplicate them on card stock. Plasticine clay such as "Clayola" works well and can be re-used. Clayola comes in one pound packages. Each package contains four sticks of clay. Marbles and crayons are used for boat cargo because of their uniform sizes and resistance to water damage. This activity will cause water spills. Provide ample sponges and paper towelling to clean up the excess water.

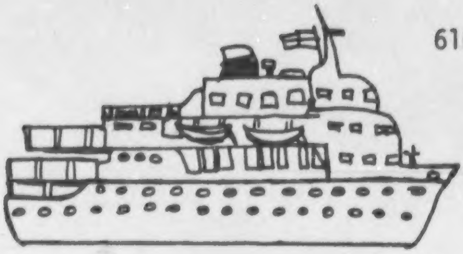
Duplicate the activity pages. One set is recommended per student. This activity is best accomplished by individual students who are grouped into teams of four for sharing ideas and results. Be aware that some of your students will face such open-ended activities with trepidation. Students are used to having a detailed procedure which they must follow. This activity challenges them to be creative, a skill it seems we seldom require. Plan to allow for an open-ended discussion in which you help your students derive the principals of displacement and floatation from their observations.

KEY

The answers to the questions on the twelve activity cards will vary because of their dependence upon the observations made by your students.

KEY WORDS

bow
balance
charts
clay
compass rose
course
float
knowledge
port
sink
starboard
stern
weighs



BOATIN'

Stern, port, starboard, bow....all of these words tell us something about boats. Compass rose, charts, courses.... all of these words tell us something about boating. But none of these words tell us how a boat works. Why do boats float? In the following activities you will have a chance to make boats float or sink.

Materials:

activity

cards

clear plastic container, dishpan, plastic shoe box
or similar container

water

clay, plasticine (about ¼ to ½ pound).

marbles (people)

plastic cups

aluminium foil

balance

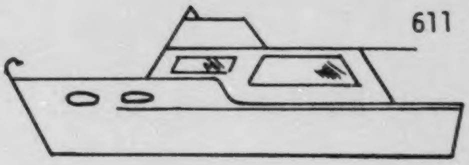
crayons (cargo)

sponges, paper towels for clean-up

Procedure:

1. Obtain a set of activity cards. Begin with card #1 and follow the directions found on the card. Complete all 12 cards.

Boatin' 1



Obtain a block of clay

What do you think will happen if you drop the clay in water?

TRY IT!

What did happen to the clay when you dropped it in the water?

Can you shape a piece of clay so that it will float?

TRY IT!

Write down the different ways in which you tried to make the clay float. Circle the ways that worked.

Boatin' 3

Obtain 5 or 10 marble-people.

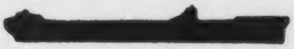
Float your best boat from #2. See how many marble-people you can add before the boat sinks. Write down the number of marble-people your boat can carry without sinking. ________________.

How can you change your boat so that it will carry more marble-people?

TRY IT!

In the space below, write how you made your boat better.

Boatin' 2



Divide your block of clay into three equal pieces.

Make three clay boats with different shapes.

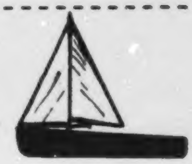
Try floating your three boats.

In the space below: For each boat, draw a picture that shows its shape.

Write a sentence about each boat.

Circle the drawing of the boat which floats best.

Boatin' 4



Practice using a balance to weigh something. Make sure you know how to use the balance.

Use the balance to answer the following questions. Write the answers in the spaces below the questions.

A. Which weighs more, your best boat or a not-so-good boat?

B. Which weighs more, your best boat or the weights it can hold?

Float your best boat. Add crayon-cargo until the boat sinks. Write down the number of crayons your boat can carry without sinking. ______________.

C. Which weighs more, the crayon-cargo your boat can hold or the marble-people your boat can hold?

Boatin' 5

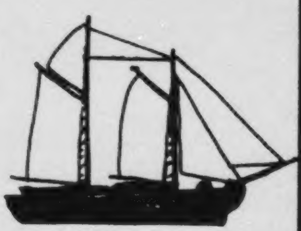
Keep your best boat. Use the clay from one of the other two not-so-good boats to try to make a boat that can hold more marble-people.

The new boat will hold ___________ marble-people (Fill in the number.)

Try your old best boat again.

Will the same boat always hold the same number of marble-people?

Boatin' 8



Use a balance to help answer the following questions.

A. Find two clay boats that weigh about the same. See if they both carry the same number of marble-people without sinking. If they don't, write down why you think they do not.

B. Find two plastic cup boats that do not weigh the same. Find out which one will carry more marble-people without sinking. Why do you think it holds more marble-people?

Boatin' 6

Here are some questions to work on with your partners before going on.

1. Look at each person's best boat. How many marble-people does each hold?

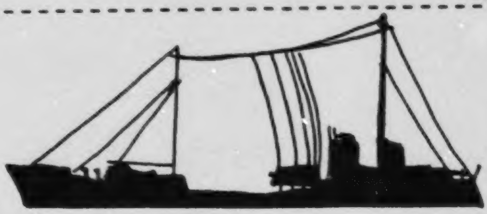
   Boat A.____ Boat B.______ Boat C.______ Boat D.______

2. Why do you think the boats hold a different number of marble-people?

3. Which shape seems to hold the most marble-people?

4. Work together to make the longest list you can of ways to make a clay boat hold more marble-people. Write the list on a separate sheet of paper.

   Hint: Think about your best boat and also about the boats that sank.



Boatin' 7

Obtain a plastic cup boat.

Make the plastic cup boat float next to your best boat.

How does each boat sit in the water?

Which one do you think will carry more marble-people?

TRY IT!

How many marble-people did your clay boat hold? __________

How many marble-people did your plastic cup boat hold? ________

Which do you think is a better boat? Why?

Boatin' 9

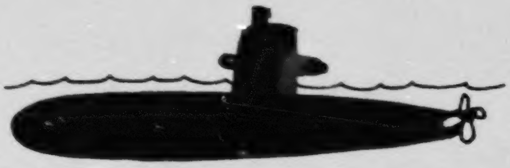
Use your best boat.

How many marble-people can it hold without sinking in the water? ____________.

Take your boat out of the water. Pour a cup of salt into the water. Stir the salt until it dissolves.

Put your boat back in the water. Add the number of marble-people you wrote in the blank above. Add more marble-people. Will your boat hold more marble-people now?

If your boat holds a different number of marble-people, write down why you think it does.



Boatin' 11

Obtain three pieces of aluminum foil.

Make three aluminum boats:

A. one with high sides.
B. one with medium sides.
C. one with low sides.

Guess which one will hold the most marble-people. __________.

Test each boat.

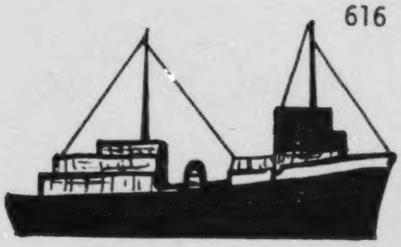
Which one really holds the most marble people?

Make a clay boat the same size as the best aluminum boat.

Will the new clay boat hold the same number of marble-people as the aluminum boat?

Make a guess. TRY IT! Record your answer __________.

Boatin' 10



Obtain a piece of aluminum foil.

Can you make the foil float?

TRY IT!

Guess how many marble-people your new boat will hold? ________.

Add marble-people to your aluminum boat. How many will your aluminum boat hold? ____________.

Was your guess right?

Boatin' 12

Use your new found knowledge to answer the following questions in complete sentences.

A. Johnny Come Lately is new to your class. You want to help him build a clay boat. How would you tell him to make his clay boat?

B. What could he do to make his boat hold more marble-people?

C. What could you tell him about plastic cup boats?

D. What would you tell him about aluminum boats?

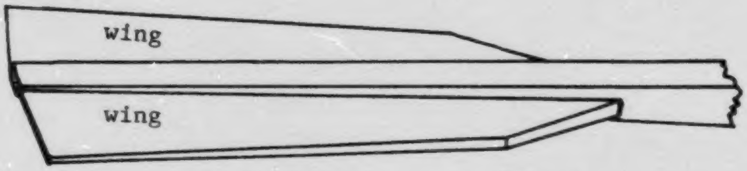
TEACHER BACKGROUND - Grand Banks

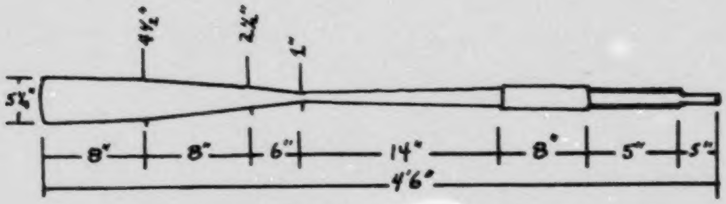
"Grand Banks" provides you with an opportunity to marinate the industrial arts curriculum. The activity is designed to involve your students in the actual construction of an inexpensive rowing dory. The plans were modified from and presented here with the permission of National Fisherman (October 1980). The originator of the plans writes about this boat saying "she has been a fun, safe dory for the past two years, and has never even come close to capsizing, except intentionally. My two boys have learned about taking care of their own boat in the best way - by experience." While this activity presents some logistical challenges, we can paraphrase the boat builder's sentiments - the best way for your students to learn about boats is through building one.

Several approaches are possible with this activity. For example, you might build a demonstration model with your class, you might make special arrangements with the shop teachers to have the students you share in common build a dory under the shop teacher's supervision, you might have parents involved in the construction at home, or you might elect to have small groups of students construct dories in your classroom. While the actual layout and construction is simple, it is imperative that you build a sample dory before you turn your students loose on the project.

Check with your industrial arts department to learn what specific safety precautions they recommend for students working with hand tools and hand-held power tools. Provide goggles for eye protection and warn your students about the dangers inherent in wearing loose fitting clothing and long hair when operating power tools. The loose clothing or long hair can be pulled into the moving parts causing injury to the student. Warn your students to demonstrate similar caution when using sharp tools. Follow the manufacturer's directions when using fiberglass resin and cloth. Marine epoxies are also suitable for this application. Regardless of the product, provide ample protection for your students through adequate ventilation, dust masks and/or respirators, and gloves.

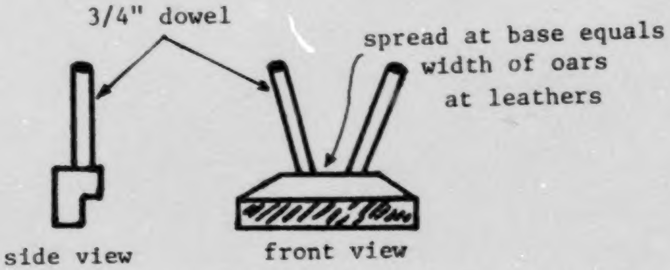
Oars and oarlocks may be purchased. Alternatively, oars may be made from ash or spruce using the drawings included below:




4½"
2¼"
1"
5¼"
8"
8"
6"
14"
8"
5"
5"
4'6"

Three pieces of wood are needed for each oar; the long main piece or loom which also incorporates the middle part of the blade, and the wings or side pieces of the blade. Mahogany and cedar are often used for the wings of oar blades in glued oars.

Two tholepins units patterned after the one shown below can be used in place of conventional oarlocks.


3/4" dowel
spread at base equals
width of oars
at leathers
side view
front view

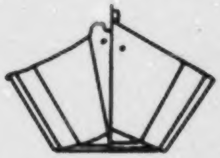
Further information, including additional dory plans may be found in:

Gardner, John. 1978. The Dory Book.
International Marine Publishing Company. 275 pages.

"Grand Banks" is a challenging, fun activity that will introduce your students to boating. Take the risk and try it!

KEY WORDS

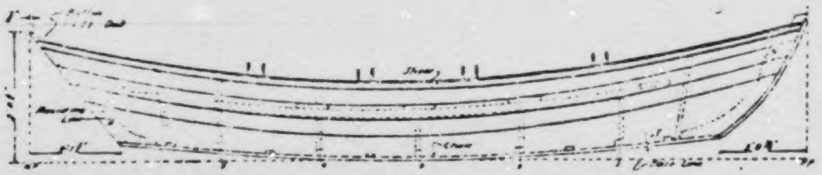
adapted
batten
bow
C-clamp
catalyst
centerline
chalkline
chart
cod
compass
curve
dory
fiberglass
flared
flush
frame
framing square
galvanized
grand banks
halibut
layout
lengthwise
mirror images
navigation
oars
oarlocks
parallel
port
resin
rocker
rub rails
saturate
secure
set a nail
starboard
stern
thread
tombstone
widthwise



GRAND BANKS

Whale watching is more complicated than meets the eye. First you have to know how to locate the whales. To find the whales you have to be able to use a compass and to read a chart. You have to know something about navigation so that you can get out to the whales and home. You have to know what to call things on the boat and you have to know what makes boats work. Now that you know all of these things, at least one important item remains. You still need a boat. In the following activity you will have a chance to build a small boat.

Traditionally, small boats were built for specialized purposes. The boat described below is a small version of a boat called the Grand Banks dory. In the mid-1800's sailing boats fished for cod or halibut some 100 miles off the Newfoundland, Canada coast. When the sailing boats reached the fishing grounds, or "grand banks," the fishermen lowered the dories into the water. The sailing boat would disappear, leaving the dory and its one or two person crew behind to fish. Using hand lines the fishermen would fish all day. If all went well, the dories were recovered by the sailing boat later in the day. The sailing boat was called the mother ship.



Dories were perfectly adapted for being carried aboard a mother ship. The flared sides allowed a half dozen dories to be nested one inside the next. In the water, the high ends kept the boats dry even with great loads of fish.

The classic dories from the Grand Banks inspired the boat you are about to build. Build it with care and you'll have a fun, safe vessel.

Materials:

one 4' x 8' x ¼" or 3/16" sheet of A-C/X plywood

one wooden batten (a flexible stick about 3/4" x ¼" x 8 feet long)

20-30 shingle nails (1 3/4" galvanized)

framing square

saw

hammer

pliers

drill and drill bit

iron tie-wire

one 12½" x 26½" piece of 3/8" or thicker exterior plywood

two ½" x 3/4" x 8' fir or pine strips

pencil

tape measure

chalk line

1 - 2x4 (6 feet long)

2 - 2x4 (16" long)

2 - 2x12 (10" long, approximately)

10 - 10d nails

2 - 6" C-clamps

4" fiberglass cloth

resin

scissors

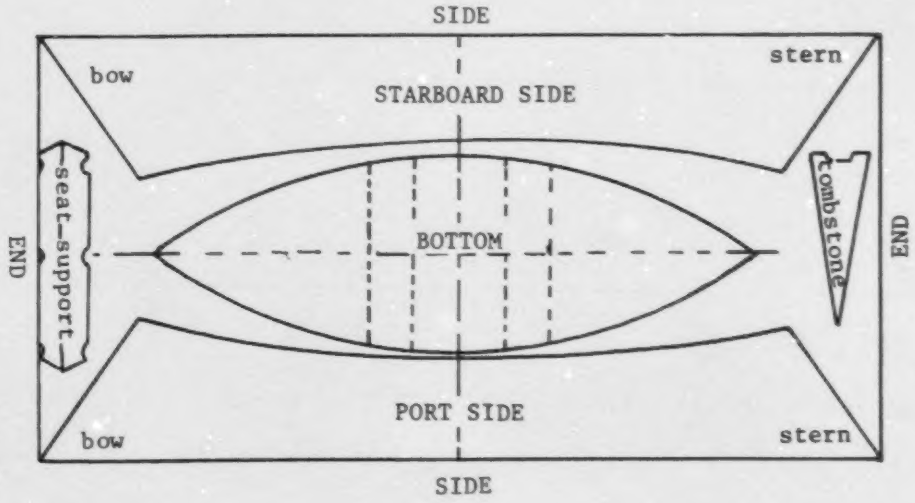
gloves

dust mask

paint brush

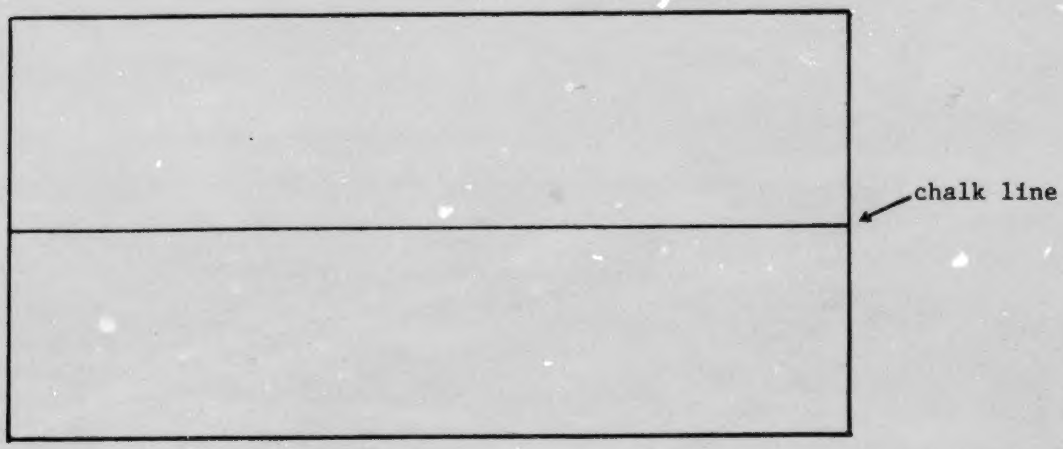
Procedure:

1. Obtain a sheet of plywood, a wooden batten, 20-30 shingle nails, chalk line, framing square, tape measure, pencil, and hammer.
2. You will use the tools to lay out the sheet of plywood before you cut. When you are finished the sheet will look something like the picture below:

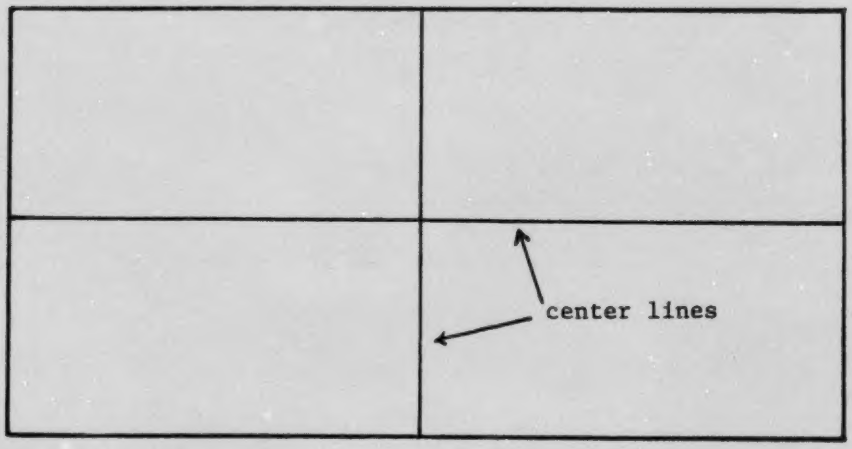

SIDE
bow
stern
STARBOARD SIDE
seat-support
END
BOTTOM
tombstone
END
PORT SIDE
bow
stern
SIDE

Layout Directions - Bottom

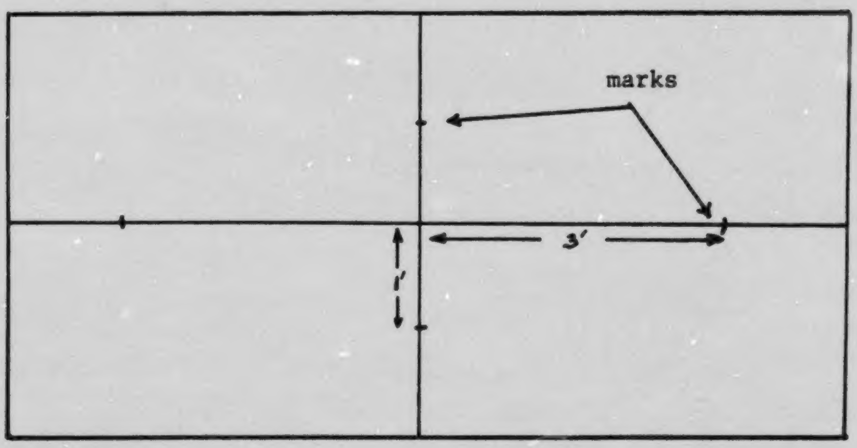
3. Lay the plywood sheet on a convenient working surface. Use the tape measure, pencil and chalkline to divide the sheet in half lengthwise. This is easy. Along one end, measure up two feet from the bottom and make a pencil mark. Do the same thing on the other end. Have your partner hold one end of the chalk line on one of the marks. Pull the string tight and lay it across the second mark. While holding the string tightly, pick up one end of the string and let it go. This procedure is called "snapping a line." If all has gone according to plan, your sheet of plywood will have a line running lengthwise down the center. Your sheet should look something like this:



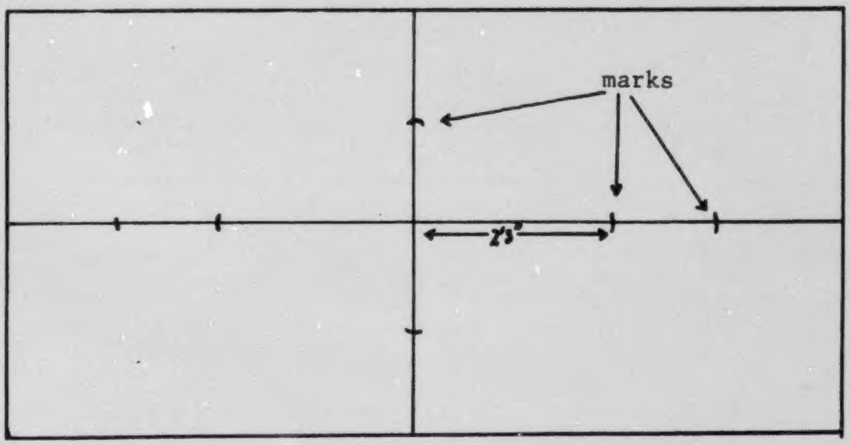
4. Use the same technique to divide the sheet of plywood in half, widthwise. Instead of measuring up two feet, you will need to measure across four feet. Snap a line at the four foot mark. Your sheet of plywood should now look like this:



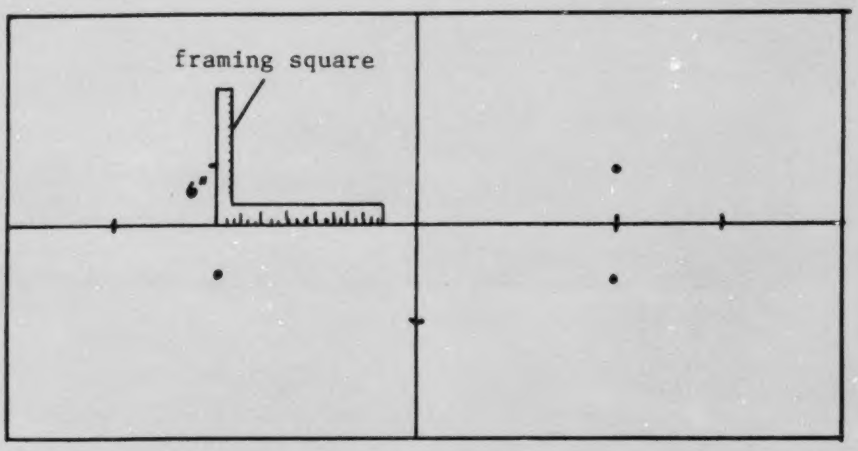
5. The center of the sheet of plywood is the point where your lines cross. Use your tape measure and pencil to make pencil marks 3 feet from center along the length and one foot from the center along the width. Your sheet of plywood should look like this:



6. Use your tape measure to make pencil marks 2' 3" from the center along the length. Your sheet of plywood should now look like this:

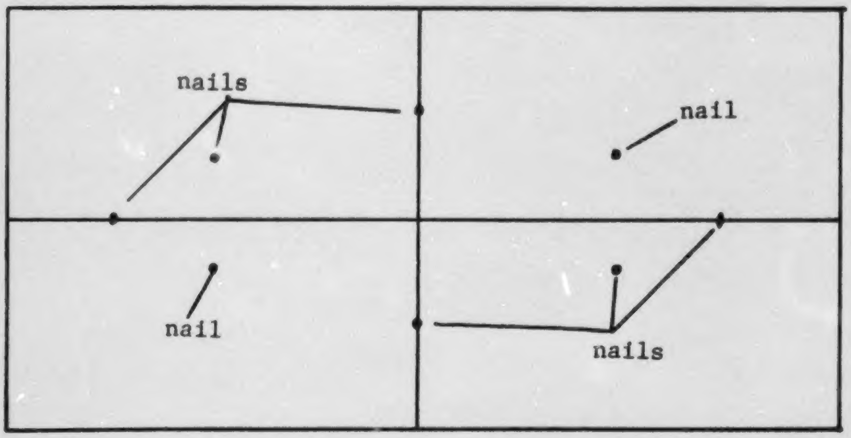


7. Use your framing square and pencil to make pencil marks 6" above and below your 2' 3" marks. The drawing below shows you how to do it.

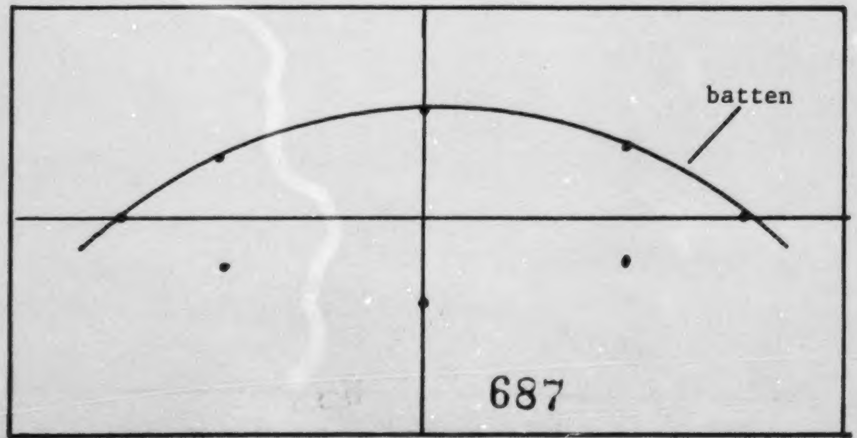


8. Set a nail at each of the four marks you made in step 6. This means that you will hammer in one shingle nail at each of the marks. Take care not to drive your nail through the sheet of plywood.

9. Set nails at the one foot and three foot marks from the centerline. Your sheet of plywood should look something like this:

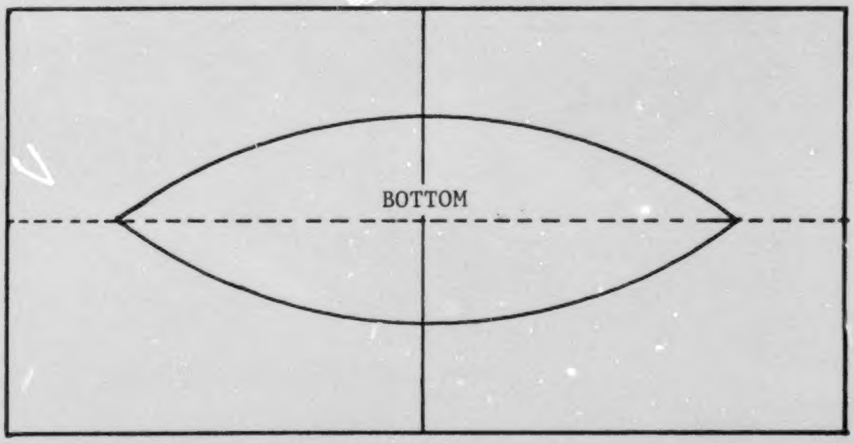


10. Have your partner hold one end of the batten against one of the 3' nails. Gently curve the batten around the 2', 3', and 1' nails until it is against the other 3' nail. Your batten and plywood should look something like this:

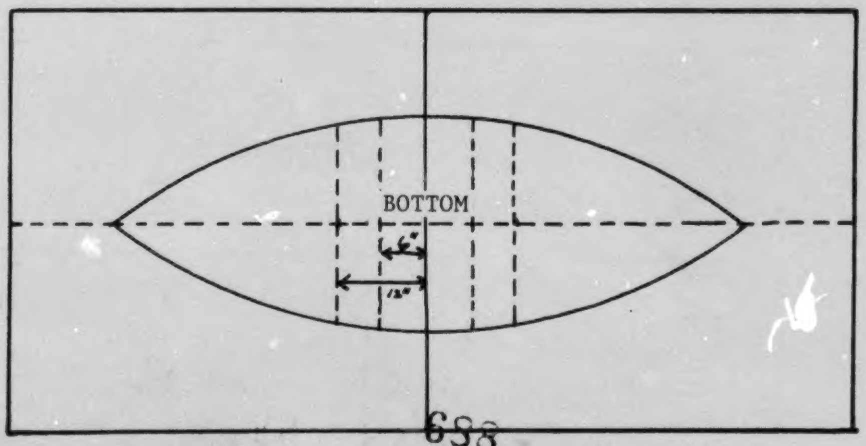


11. Have another person hold the second end or you may secure it with a nail alongside the batten. The curve of the batten will determine the shape of the bottom. Run your pencil along the base of the batten to draw the curve on your sheet of plywood.

12. The right half and left half of the dory are mirror images. Follow steps 10 and 11 to draw the curve for the other side of the dory. Remove batten and nails. Your sheet of plywood should now look like this:



13. The layout of the bottom is finished except for two pairs of marks. Use your tape measure, framing square and pencil to make lines across the bottom 6" and 12" from the centerline. Your completed bottom should look like the following:

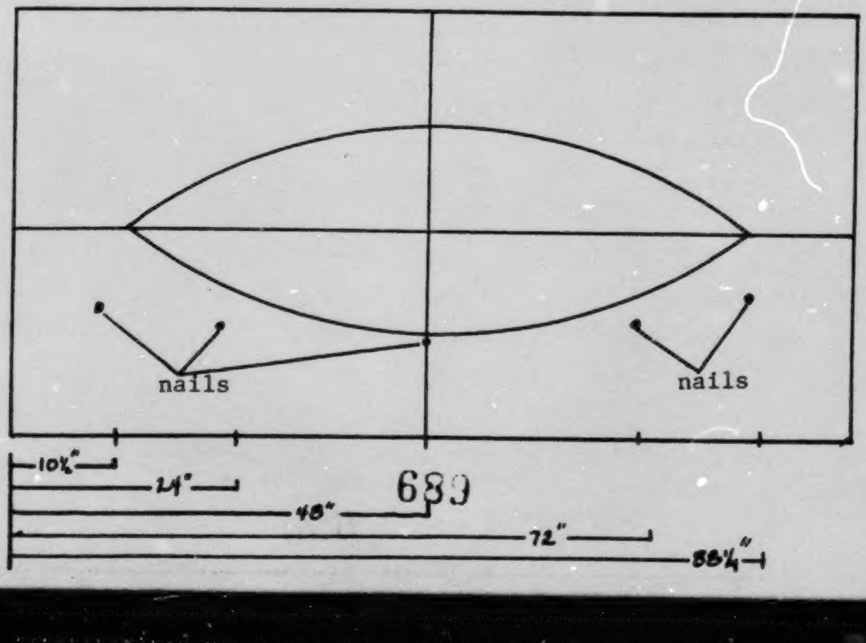


Layout Directions - sides

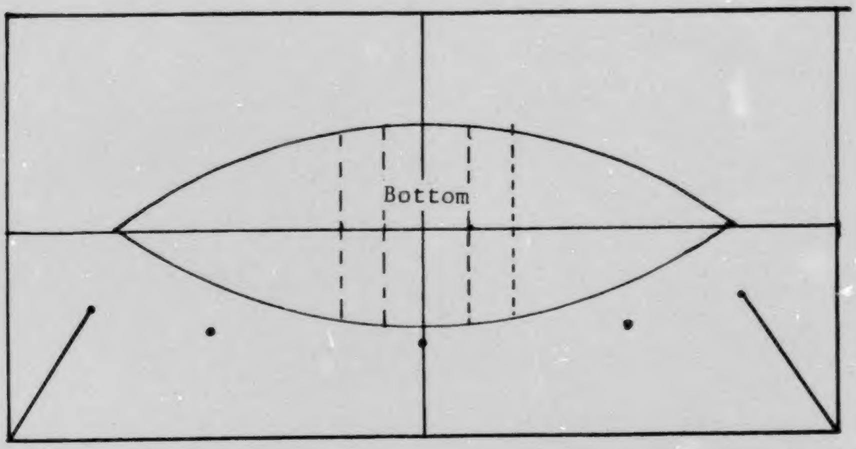
1. Using your tape measure and pencil make pencil marks along one of the long sides of your plywood sheet at the following distances from one end. (10½ inches, 24 inches, 48 inches, 72 inches, & 88¼ inches.)
2. Use your framing square to measure in 14 inches from the 10½" mark you just made. Set a nail at this point. This nail will help determine the shape of the side. Use the same procedure at the other four marks you have made. The distances in from the side are given below:

Distance From End	Distance In From Side (Location of Nail)
10½"	17"
24"	14¼"
48"	11½"
72"	11½"
88¼"	14½"

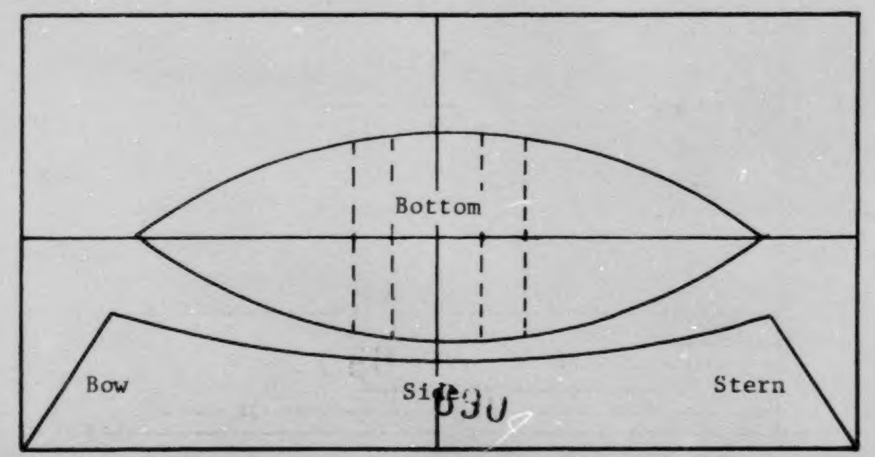
Your plywood sheet should now look something like the picture below:



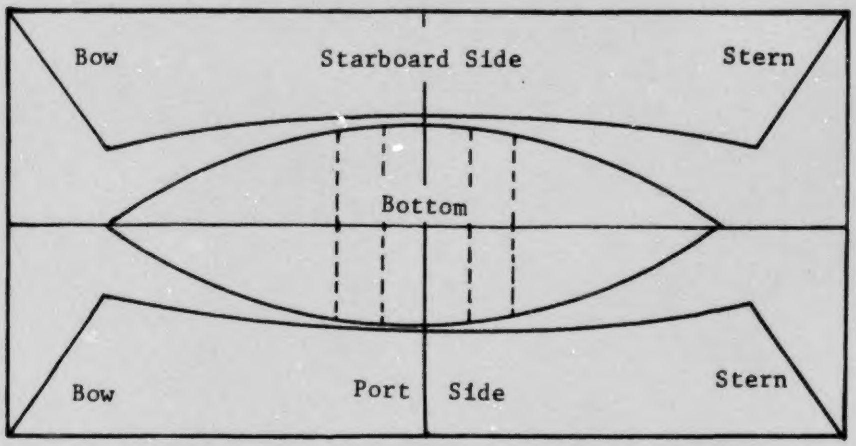
3. Use a pencil line to connect the closest corner of the plywood sheet with the nail 10½" in from the end.
4. Use a pencil line to connect the closest corner of the plywood sheet with the nail 88¼" in from the end. Your plywood sheet should now look something like this:



5. Have your partner hold one end of the batten against the 10½" nail. Cently curve the batten around the 24", 48" and 72" until it is against the 88¼" nail. Secure one end with a nail alongside the batten. The curve of the batten will determine the shape of the side. Run your pencil along the base of the batten to draw the curve on your sheet of plywood. Remove batten and nails. Your plywood sheet should look something like this:



6. Repeat steps 1 through 5 to lay out the other side. When both sides are laid out your plywood sheet should look something like this:

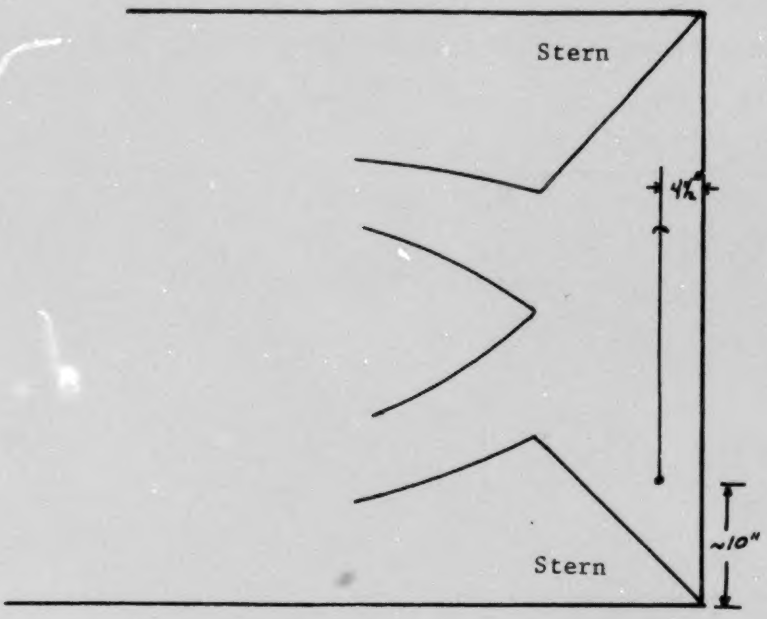

Bow
Starboard Side
Stern
Bottom
Bow
Port Side
Stern

Layout Directions - Tombstone

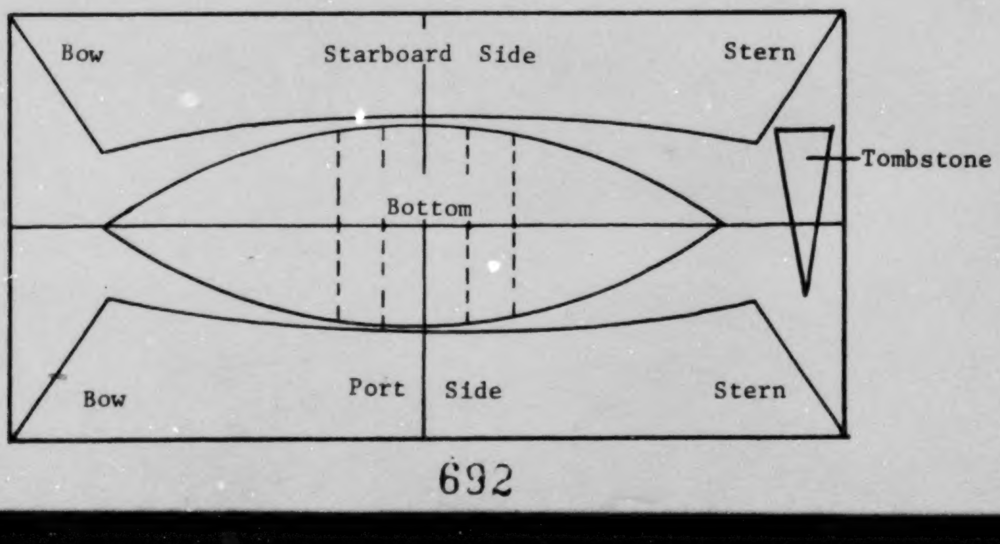
The tombstone is a triangular stern piece which holds the two sides together.

1. Draw a line 4½" in from the "stern" end of the sheet of plywood and parallel to the end.
2. About 10" in from one side make a pencil mark crossing your parallel line.

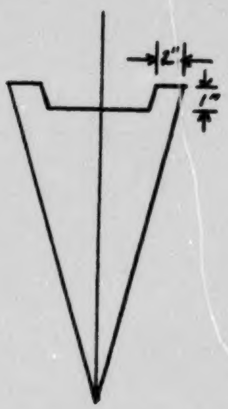
3. From your 10" line, measure along the parallel line for a distance of 18½". Make another cross mark at this point. This part of your sheet of plywood should now look like this:


Stern
4½
~10"
Stern

4. Use your framing square to measure in 4½" from your 18½" mark. Draw a line from the edge of the sheet to the point 4½" in from the parallel line.
5. Use a pencil line to connect the ends of your line at the 18½" mark to the pencil mark you made about 10" in from the side. Your plywood sheet should now look something like this:

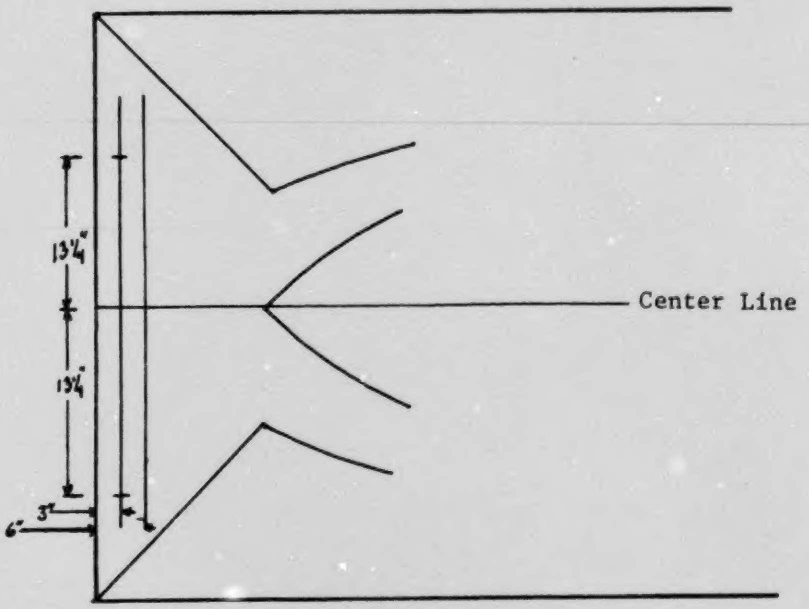

Bow
Starboard Side
Stern
Tombstone
Bottom
Bow
Port Side
Stern

6. To give your tombstone a little class finish off the end by making the following changes:



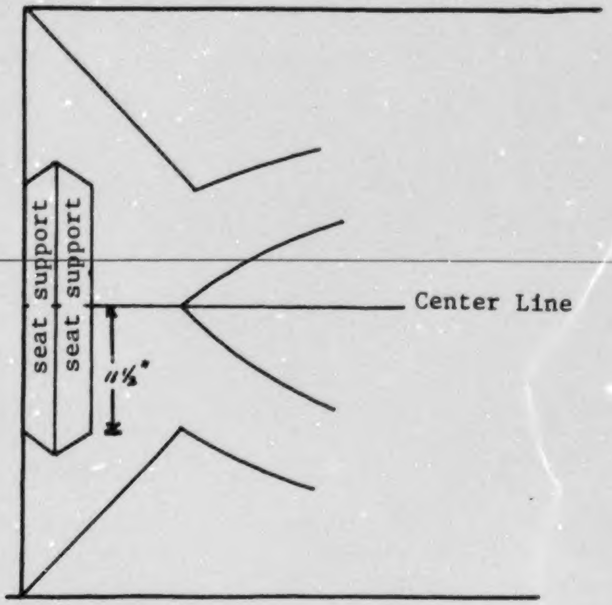
Layout Directions: Seat Supports

1. Draw lines 3" and 6" in from the "bow" edge of the plywood sheet and parallel to the edge.
2. Your parallel lines cross the chalkline you made to mark the centerline of the plywood sheet. Along your 3" line measure 13¼" toward each side. Mark these points. This part of your sheet of plywood should look something like this:

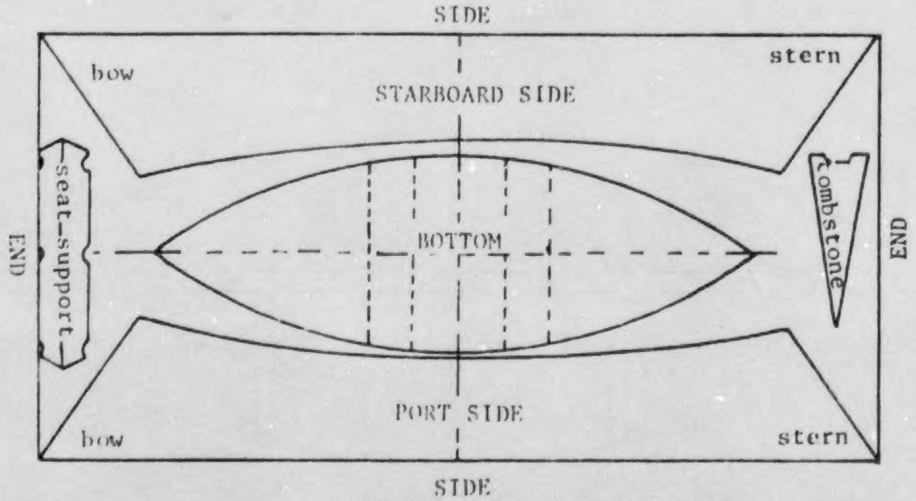


3. Along the edge and along your 6" line, measure 11½" toward each side. Mark these points.

4. Use a pencil line to connect your 13¼" marks with your 11½" marks. This part of your sheet of plywood should now look like this:

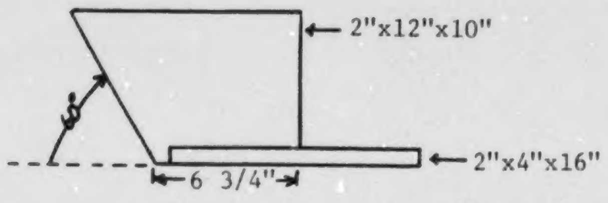

seat support
seat support
11½"
Center Line

5. Your seat supports will run across the bottom of the boat. Pencil in three drain holes along the edges of the seat supports. The holes are shown in the next picture. Your completely laid out dory will look like the picture below:

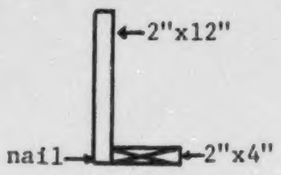

SIDE
bow
STARBOARD SIDE
stern
seat-support
END
BOTTOM
tombstone
END
PORT SIDE
bow
stern
SIDE

Assembly

1. Assembling the sides and hull will be much easier if you first make two identical frames. Use the drawings below as a guide:

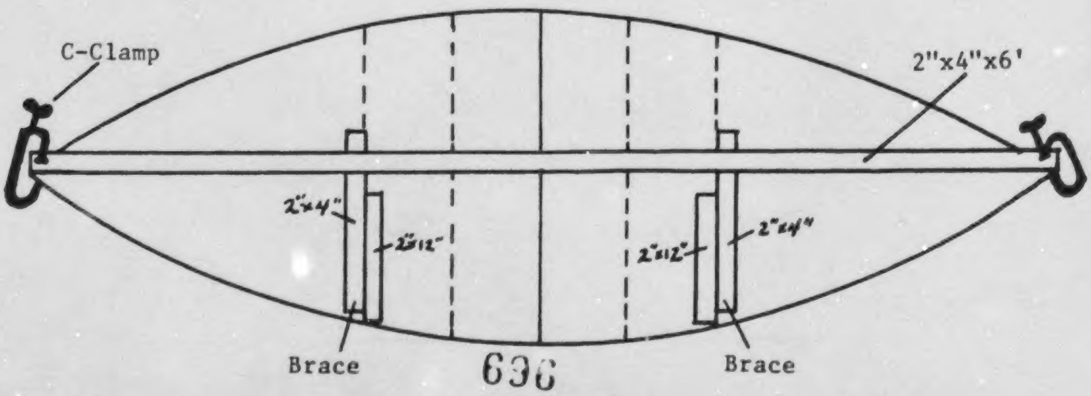


Side View

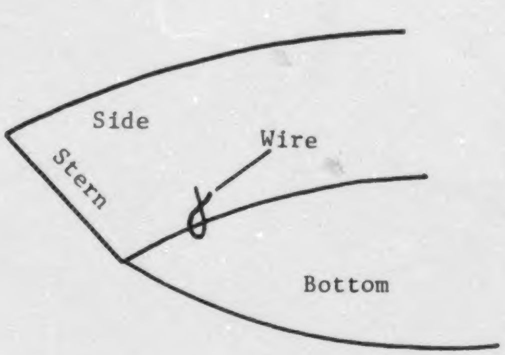


Front View

2. Use a saw to cut out the sides, bottom, tombstone and two seat supports.
3. Place the two frames parallel to the marks for the seat supports and 12" from center line. You may want to tack the frames in place or have your partner hold them while you go on to the next step.
4. Lay the six foot long 2" x 4" along the center line and on top of the two 2" x 4"'s of the braces.
5. Place a C-clamp at each end of the six foot 2x4. Tighten the C-clamps to bring the bottom piece up to the 2x4. This curve in the bottom is called a rocker and will make your boat easier to row. The completed set up should look something like this:

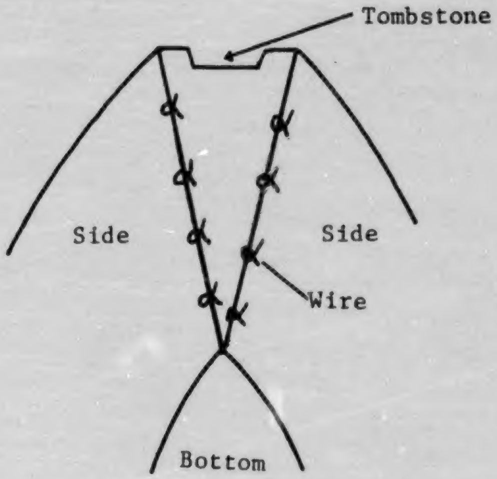


6. Position one side so that the stern end of the curved edge is flush with one end of the bottom. Drill matching holes in the bottom and side near the end. Thread a short length of tie-wire through the two holes. Use your pliers to twist and tighten the wire. You will use this technique to hold your boat together. The stern should look something like this.



7. Gently curve the side around the frame. Hold in position at the bow. If necessary, you may let the side hang over the bottom by ¼". Drill and wire the side to the bottom near the bow.
8. Near the top of the side, tack the sides to the frames with a single nail.
9. Drill and wire the side to the bottom. Make your ties 4 or 5 inches apart.
10. Remove the two frames and replace them so they may be used to support the remaining side. Follow steps 3-10 to attach the second side to the bottom. Remove the six foot 2"x4" after you have the stern in position.
11. Drill and wire the two sides together at the bow. If necessary trim the sides to secure a good fit.

12. Use your drill and wire technique to attach the tombstone to the two sides at the stern. Your tombstone should look something like the picture below:



13. Remove the frames. Position the two seat supports on the marks you made on the bottom. Secure the supports with a nail through the end of the support into the side.
14. Use two ½" x 3/4" x 8' strips for rub rails. These are attached by drilling and wiring to the top of each side.
15. By now your sheet of plywood should look like a boat. You may notice that there are a lot of holes along the seams and a lot of wires. Obtain some 4" wide 10 ounce fiberglass cloth and a pair of scissors. Cut lengths of cloth to fit between all of the pieces of wire. It is a good idea to wear gloves and a dust mask when working with fiberglass cloth.

16. Follow your teacher's directions for mixing the resin and catalyst. Use a paint brush to saturate the pieces of cloth you have placed between each pair of wires. Clean the brush and let the resin dry overnight.
17. Remove the wires. Cut additional pieces of fiberglass cloth to cover the wire holes along the cloth covering the wire holes. Clean the brush and allow the resin to dry before proceeding.
18. Cut two pieces of fiberglass cloth the length of the outside bottom, a piece the length of the bow and two pieces the length of the stern. Again use a paint brush to saturate the pieces of cloth. Clean the brush and allow the resin to dry
19. The 12½" x 26½" piece of 3/8" or thicker plywood will serve as the seat. Use the galvanized nails to fasten the seat to the supports.
20. Your boat is now finished except for paint, oarlocks and oars. Obtain what you need to finish your boat at a local sporting goods store. Happy boating!

TEACHER BACKGROUND - Trim or Swim

Water safety is largely a matter of common sense and experience. "Trim or Swim" provides you an opportunity to increase the experiences of your students and to sharpen their common sense. Most water related fatalities stem from inappropriate action. On water, small mistakes or miscalculations can have serious consequences. The activities included in "Trim or Swim" are adapted from ideas found in Girl Scout Camping Standards publications #86-96 and #92, 96. These flyers are available from the Girl Scouts and are recommended reading. Additional information about water safety and PFD's may be obtained by contacting your state boating authority, U.S. Coast Guard Auxiliary, U.S. Power Squadron, Red Cross or your nearest unit of the U.S. Coast Guard. The pamphlet "About....Life Jackets 'n' PFD's...with EPH*" is available for 25¢ from Stearns Manufacturing Company, St. Cloud, Minnesota 56301.

Parts I to IV allow your students to experiment with some factors influencing boat stability. These activities are appropriate whether or not your students have actually built the dory described in "Grand Banks." While Parts I-IV logically follow either "Grand Banks" or "Boatin'," Parts V and VI are designed primarily to provide actual experience in and on the water. Advance planning and contact with your local swimming pool are necessary for success. Exercise utmost caution in these activities. Work with trained instructors and do not force unwilling students to participate. Find out which of your students cannot swim and arrange special help for them with the life-guard at the pool. Swim-in-clothes training is recommended before doing "Part V - PFD" if you plan on having your students wear clothing during the PFD activity.

Duplicate the activity pages. One set is recommended per student. These activities are best accomplished in groups of three or four. While the activities are set up in a game format, do not overstress the competition. A convenient place for a break occurs between activity IV and V. As you discuss these activities, help your students make the logical extensions from the models to real life situations.

KEY

Part I - Back to Basics

1. The freeboard of the toy boat is reduced as the marbles are added.

2. The freeboard of a real boat is reduced as you add weight. The point to begin emphasizing here is that overloading a boat with people and/or gear reduces freeboard and increases the danger of swamping. Boaters need to stay within the load limits of their boat.
3. The likelihood of swamping your boat [✓ *increases*] / *decreases* as you reduce the freeboard. (The correct answer is circled).
4. While answers will vary slightly, most of your students will want to avoid overloading their boats so that they may avoid swamping. Swamping can lead to injury and death in extreme conditions.

Part II - Stormy Weather

1. Waves cause the boat to rock.
2. Waves reduce the freeboard, increasing the danger of swamping.
3. In stormy weather, a small boat can safely carry *more* / [✓ *less*] weight than in calm weather. (The correct answer is circled).
4. Your students will want to avoid stormy weather in small boats to reduce the risk of swamping. Adverse weather reduces the freeboard and increases the danger of swamping. Emphasize the fact that small boat operators need to be aware of and allow for weather.

Part III - Trim

1. Answers will vary depending upon the experimental results. Generally, the combination of clothespins on the gunwale and towing proves to be the most unstable and, hence, to take the fewest clothespins to effect swamping.
2. The stability of the boat decreases as weight is added or moved. Emphasize that shifting weight causes a decrease in stability. Weight needs to be balanced to reduce instability.
3. In a small boat, the most stability is attained by sitting near the center (actually, just slightly toward the stern, along the center line).
4. A sudden application of power decreases the boat's stability. Gentle rowing and gentle take-offs with power boats, reduce the instability that occurs when a boat gets underway.

Part IV - Standing Up

1. Raising the center of gravity *increases* / [✓ *decreases*] the stability of the boat. (The correct answer is circled).
2. The most obvious way to raise the center of gravity in a real boat is to stand up.

3. [✓ *Sitting*] / *Standing* increases your stability in a small boat. (The correct answer is circled).

4. The conditions listed are correctly placed in the table below.

Stable	Unstable
sitting in the center of the boat.	adding extra weight
sitting low in the boat	moving all weight to the stern
	moving all weight to the bow
	standing in the center of the boat
	pushing or pulling the boat rapidly

KEY WORDS

afloat
aground
application
balance
board
bow
calm
capsize
center of gravity
chart
chorus
distribute
fastenings
freeboard
gear
gunwale
HELP
HUDDLE
instability
keelson
lengthwise
likelihood
midships
navigate
overloading
PFD
power source
refloat
safety
secure
stability
stern
stow
swamp
thwart
treading water
trim
waterline

TRIM OR SWIM

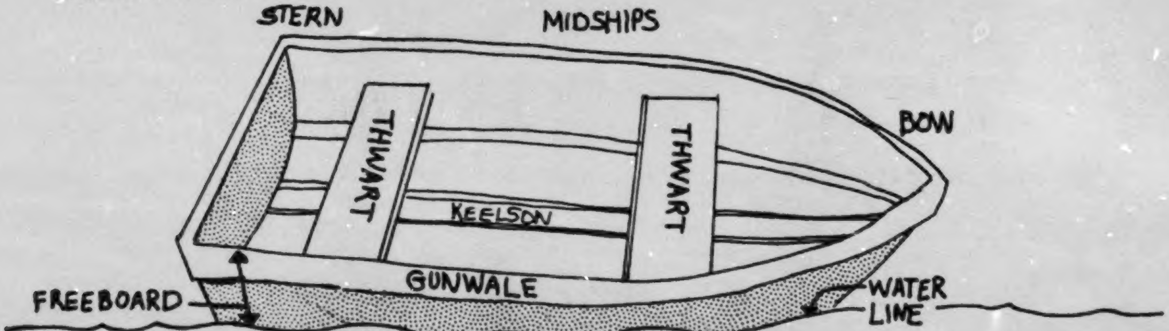
Surely you're now ready to go whale watching. You have your boat. You can call its parts the right names. You can read a chart and navigate. What else do you need to know? Water activities can be fun. They can also be dangerous. One more important thing to consider before testing your boat is safety. The following games will show you some basic safety tips. Play the games with toy boats first.

Materials:

dish pan, sink, tub or similar container
marbles
string
clothespins
holepunch
scissors or knife
string
PFD

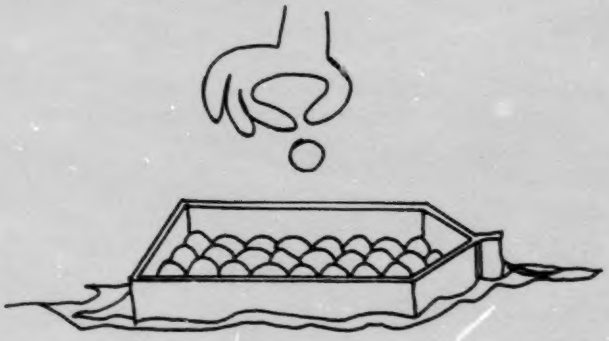
Procedure:

The drawing below will help you complete the following activities.


STERN
MIDSHIPS
BOW
THWART
THWART
KEELSON
GUNWALE
FREEBOARD
WATER LINE

Part I - Back To Basics

1. For these activities, work in groups of three or four. Obtain a milk carton and a pair of scissors.
2. Cut the milk carton in half lengthwise to make two toy boats.
3. Take turns adding single marbles to your boat. The group member whose marble causes the boat to swamp (fill with water) loses. Record the number of marbles taken to sink the boat: ____________ marbles.



Analysis and Interpretation:

1. What happens to the freeboard (see drawing above) of your toy boat as you add marbles?
2. What happens to the freeboard of a real boat as you add weight?
3. The likelihood of swamping your boat increases / decreases as you reduce the freeboard. (Circle the correct answer).
4. Why do you want to avoid overloading your boat?

Part II - Stormy Weather

1. Empty and refloat your toy boat from Part I.
2. Add one half of the number of marbles it took to swamp your boat.
3. Two or three of the team members will supply hot air. The other member will be the observer. Make waves on the water surface by gently blowing from one end of the dishpan.

Analysis and Interpretation:

1. What do the waves do to the boat?

2. What effect do the waves have on the freeboard?

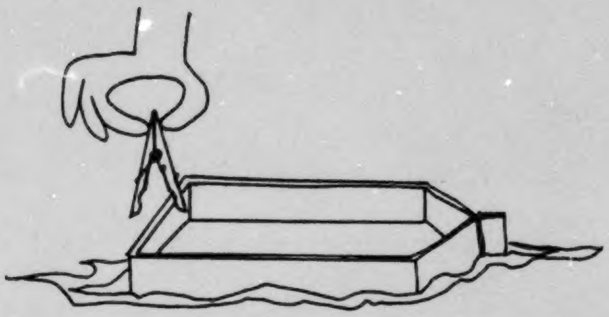
3. In stormy weather, a small boat can safely carry more/less weight than in calm weather. (Circle the correct answer).
4. Why will you want to avoid stormy weather in your small boat?

Part III - Trim

"Trimming" a boat means moving the weight in the boat to help the boat balance. A boat with the bow high in the air and the stern low in the water is not in trim.

1. Empty and refloat your toy boat. Take turns clipping clothespins to the stern. The team member whose clothespin causes the boat to swamp loses. Record the number of clothespins taken to swamp the boat:

   ________________clothespins.



2. Empty and refloat your toy boat from step 1.
3. Take turns adding clothespins to one gunwale. Again, the team member whose clothespin causes the boat to swamp loses. Record the number of clothespins taken to swamp the boat: ______________clothespins.
4. Now add a tow rope to your boat. This is easy. Punch a hole near the top of the bow. Tie a string through the hole in the bow. As in step 3, take turns adding clothespins to one gunwale. Between each addition of a clothespin gently pull the boat across your water container. Have the person who added the clothespin do the pulling. Again, the team member whose clothespin causes the boat to swamp loses. Record the number of clothespins taken to swamp the boat: __________clothespins.

Analysis and Interpretation:

1. Which condition (clothespins on stern, gunwale, or gunwale and towing) took fewest clothespins to swamp the boat?

2. What happens to the stability of the boat as weight is added or moved?

3. In a small boat, where should you sit for the most stability?

4. The string was a power source for your boat. What is the effect of a sudden application of power on the boat's stability?

Part IV - Standing UP

1. Empty and refloat your toy boat from Part III.
2. Take turns adding clothespins to both gunwales. After each gunwale has three clothespins, begin clipping a second row onto the first set of clothespins. The team member who causes the boat to capsize (roll over and swamp) loses. Record the number of clothespins taken to capsize the boat: ____________ clothespins.

Analysis and Interpretation:

1. Clipping the second row of clothespins to the first raises the center of gravity of the boat. The center of gravity is the balance point for the boat.

   Raising the center of gravity increases / decreases the stability of the boat. (Circle the correct answer).

2. What is one way in which you might raise the center of gravity in a real boat?

3. Sitting / Standing increases your stability in a small boat. (Circle the correct answer).

4. The following conditions may occur in small boats. Some of the conditions tend to make the boat stable. Others tend to make the boat unstable. Place the following conditions under the proper heading:

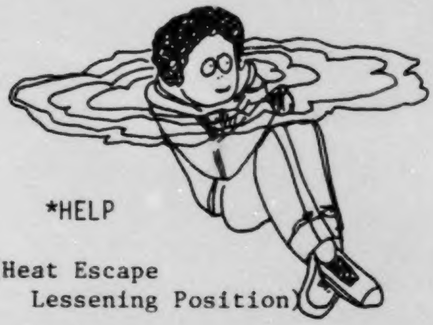
   - adding extra weight
   - moving all weight to the stern
   - sitting in the center of the boat
   - moving all weight to the bow
   - standing in the center of the boat
   - sitting low in the boat
   - pushing or pulling the boat rapidly

Stable	Unstable

Part V - PFD

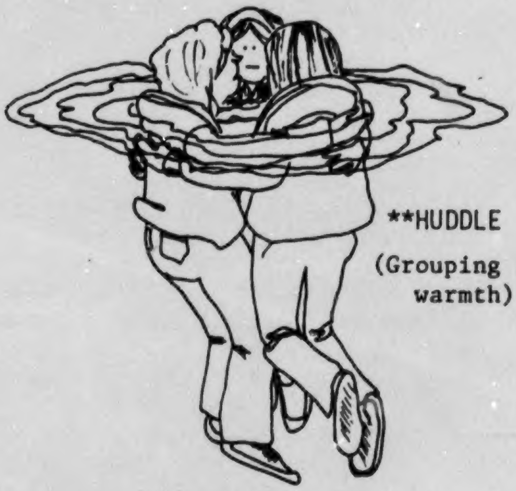
"PFD" stands for Personal Flotation Device. PFD's used to be called life jackets. A PFD can mean the difference between life and death. Before you venture out on the water be sure you have a PFD.

1. Obtain your PFD from its usual storage. Put on PFD and secure all fastenings (tie, hook, snap, zip, etc.)
2. Adjust to fit.
3. Enter the swimming pool and experiment with floating.
4. The HELP and HUDDLE positions are shown below. These positions help you keep warm in cold water.



*HELP

(Heat Escape Lessening Position)



**HUDDLE

(Grouping for warmth)

5. Assume the HELP (Heat Escape Lessening Position). Wait in HELP for the start signal from your teacher.
6. At signal, race to form a HUDDLE with the other team members from Part I above.
7. In the HUDDLE, sing a chorus of "Row, Row, Row Your Boat." The first HUDDLE to finish the song wins.

Part IV - Standing UP

1. Empty and refloat your toy boat from Part III.
2. Take turns adding clothespins to both gunwales. After each gunwale has three clothespins, begin clipping a second row onto the first set of clothespins. The team member who causes the boat to capsize (roll over and swamp) loses. Record the number of clothespins taken to capsize the boat: ____________ clothespins.

Analysis and Interpretation:

1. Clipping the second row of clothespins to the first raises the center of gravity of the boat. The center of gravity is the balance point for the boat.

   Raising the center of gravity increases / decreases the stability of the boat. (Circle the correct answer).

2. What is one way in which you might raise the center of gravity in a real boat?

3. Sitting / Standing increases your stability in a small boat. (Circle the correct answer).

4. The following conditions may occur in small boats. Some of the conditions tend to make the boat stable. Others tend to make the boat unstable. Place the following conditions under the proper heading:

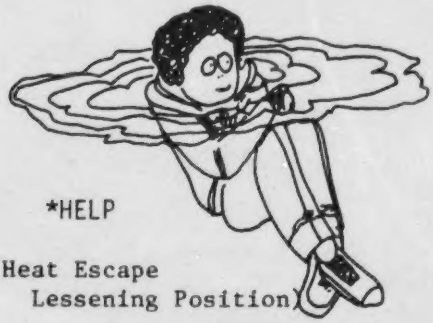
   - adding extra weight
   - moving all weight to the stern
   - sitting in the center of the boat
   - moving all weight to the bow
   - standing in the center of the boat
   - sitting low in the boat
   - pushing or pulling the boat rapidly

Stable	Unstable

Part V - PFD

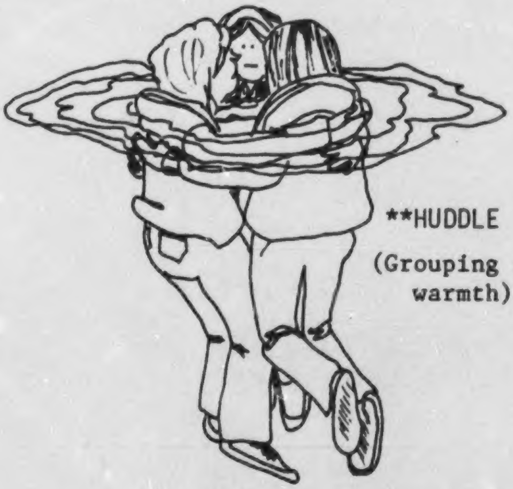
"PFD" stands for Personal Flotation Device. PFD's used to be called life jackets. A PFD can mean the difference between life and death. Before you venture out on the water be sure you have a PFD.

1. Obtain your PFD from its usual storage. Put on PFD and secure all fastenings (tie, hook, snap, zip, etc.)
2. Adjust to fit.
3. Enter the swimming pool and experiment with floating.
4. The HELP and HUDDLE positions are shown below. These positions help you keep warm in cold water.



*HELP

(Heat Escape Lessening Position)



**HUDDLE

(Grouping for warmth)

5. Assume the HELP (Heat Escape Lessening Position). Wait in HELP for the start signal from your teacher.
6. At signal, race to form a HUDDLE with the other team members from Part I above.
7. In the HUDDLE, sing a chorus of "Row, Row, Row Your Boat." The first HUDDLE to finish the song wins.

8. Here is one more activity to do before leaving the pool area. Get out of the water. Throw a PFD to one of your teammates in the water. The receiver should put on, fasten and adjust the PFD while treading water. Reverse roles and be the receiver yourself. Be sure you are familiar and comfortable with your PFD.

Part VI - For Real

Now you're ready for the real thing. If you can, try out your boat in a swimming pool or small pond. Be sure and wear a PFD. Real life is a bit different from the toy boats. With real boats, everyone in a boat is a loser when it swamps or capsizes. Remember what you learned and follow the safe boating practices listed below:

- Board one person at a time
- Keep hands free. Do not carry gear when boarding
- Hold boat alongside dock (better than over bow or stern)
- Board when boat is afloat (not beached or aground)
- Transfer weight smoothly (not by jumping or lunging)
- Step to center along the keelson (not on thwart or gunwale)
- Stay low, hold on to both gunwales
- Distribute weight evenly (slightly down in the stern)
- Sit on thwart of boat or bottom of canoe (not on gunwale)
- Sit down to pass gear aboard
- Secure loose objects
- Stow (not sit on) PFD's handy to each person (non-swimmers wear PFD's)
- Allow ample freeboard for power and weather (Motors or sails cause more tilt than oars or paddles)
- Plan moves (don't everybody change at once!)
- Single person alone in a boat:
    Trim toward midships
    Avoid bow or stern, especially in a wind
    Have a buddy ashore or in another boat

Be safe and have fun!

THE CALIFORNIA GRAY WHALE POPULATION

TEACHER BACKGROUND - December 21

"December 21" sees the gray whale we have been following reach the calving grounds at Scammon's Lagoon, Baja California, Mexico. With this activity we begin the final section of this guide. "December 21" gives a brief account of the lagoon environment and the actual birth process. It is followed by "The Numbers Game" a population growth model which uses the actual population fluctuations which have occurred in the gray whale population to explore the come-back potential of the species. "The Numbers Game" is followed by "February 21" which summarizes the scant knowledge we have regarding the northward passage of the gray whale herd. The final activity, "The Electronic Whale," is a computer simulation which provides a review of the entire southward migration.

There still exist many gaps in our knowledge of the reproductive and birth processes in the California gray whale. It appears that both male and female gray whales reach sexual maturity when they are between five and eleven years old - with the average being eight years. Their breeding season is limited primarily to a three-week period in late November and early December while they are on their southward migration. A few females seem to breed as late as the end of January in the waters near the nursery lagoons. Usually, the female breeds once every two years.

The breeding California gray whales usually follow a procedure found in few other species. A mating group is generally composed of three individuals, two males and one female. The dominant male engages in the actual copulation while the other male helps position the female.

The gray whale calf is born the next winter after a gestation period of about thirteen months. Those cows that give birth one year will not mate until the following year. As a result, approximately half of the mature females calve each winter. The calves are most often born in the quiet waters of the shallow lagoons of Baja California. Successful "at sea" births have, however, been reported for gray whales. The gray whale life span is uncertain although some are believed to live more than 60 years.

Duplicate the text pages. One set is recommended per student. This activity is best accomplished by individual students as a homework or in-class assignment. You may elect to have your class meet in small groups for a discussion of the text questions prior to your general summary discussion. As a beginning to your summary discussion, You may wish to have your students recall the route taken by the gray whales.

KEY

1. From the context clues available in the text, your students should be able to define "lagoon" as a large, shallow bay or body of water separated from the sea.
2. Scammon's Lagoon, also called Laguna Ojo de Liebre, is located in Mexico. This information is available on the map included in the text.
3. While answers may vary, most students will suggest that the whales wait for the tide to change in order to ride the incoming tides into the lagoon. This practice is an energy saver.
4. Our gray whale has traveled nearly 7,000 miles since leaving the Arctic.
5. This question anticipates the text which follows. Your students should be able to suggest a variety of advantages to birth in the shallow lagoons. These may include, the shallow bottom provides support for the female, the calm waters reduce the risk of suffocation for both cow and calf, and the lagoons provide a convenient gathering place which allows effective mutual cooperation between females.
6. A "midwife" whale helps the new calf to the surface for its first breath. This cooperation in the birth process is interesting and somewhat unusual.
7. The weight at two months may be computed as follows.

$$\frac{60\ \text{days}}{2\ \text{months}} \times \frac{50\ \text{pounds}}{\text{day}} + 2{,}000\ \text{pounds} = 5{,}000\ \text{pounds at 2 months.}$$

8. a. By being born tail first, it is thought that the whale minimizes the risks of drowning. It seems that the newborn receives oxygen via the umbilical cord until the last possible moment and with the least risk if born tail first. Your students may suggest other reasonable hypotheses.

b. For a whale born head first, shallow water births and "mid-wife" whales may provide an advantage in the speed and ease with which they permit the newborn to reach the surface for air.

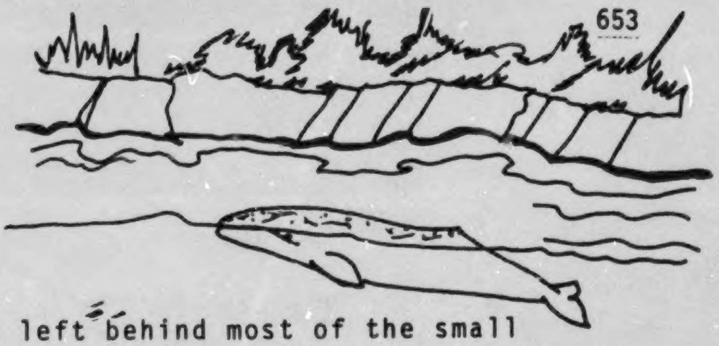
9. Gray whale females are very protective of their calves. Whalers hunting in the nursery often felt the full force of a female's wrath when they came between mother and calf. Captain Scammon gives an interesting eye witness account of one such incident:

> "When the parent animals are attacked, they show power of resistance and tenacity of life that distinguish them from all other Cetaceans. Many an expert whaleman has suffered in his encounters with them, and many a one has paid the penalty with his life....
>
> In the winter of 1856, we were whaling about the esteros of Magdalena Bay, where, in attacking sixteen whales (California grays), two boats were entirely destroyed while the others were staved fifteen times... All these serious casualties happened before a single whale was captured...
>
> After several days of rest, ...two boat's crews were selected, and the pursuit was renewed. The men, on leaving the vessel, took to the oars apparently with as much spirit as ever; but on nearing a whale to be harpooned, they all jumped overboard, leaving no one in the boat, except the boat-header and the boat-steerer.
>
> ...We were chasing a cow and calf, and I charged my boat-steerer to be careful and not touch the young sucker, for if he did, the old whale would knock us into chopsticks....A moment later the boat-steerer sung out: 'Cap'n, I've killed the calf and the old cow is after us.' Well, just about this time, I sung out to the men to pull for the shore if they loved their lives; and when the boat struck the beach, we scattered. I'll admit I never stopped to look round; but when the boat-steerer yelled out: 'Cap'n, the old whale is after us still.' I told all hands to climb trees."

The source of the name "devil fish" seems to stem from actions of this type. While the name may seem particularly well earned from a whaler's standpoint, encourage your students to view activities like the one cited above in terms of perpetuation of the whale species through protection of the young.

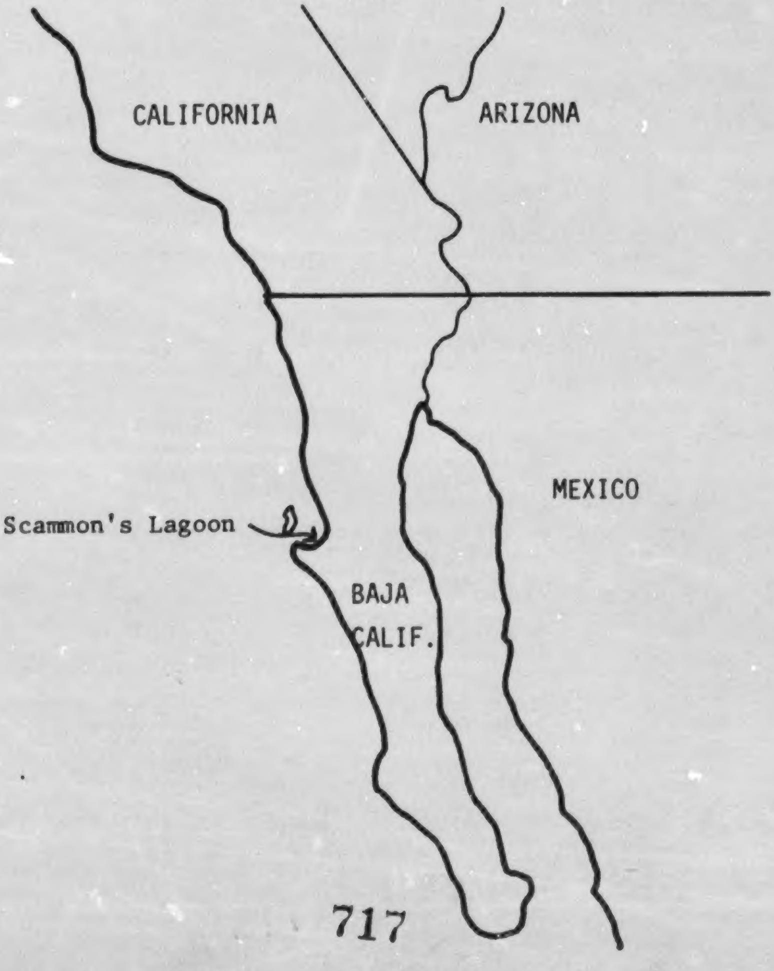
KEY WORDS

abdomen
advantage
back bays
caressed
churning
dunes
evaluate
evasive
hazardous
lagoon
mid-wife whale
nursery
offspring
relationship
rhythmic
sand bars
vapor

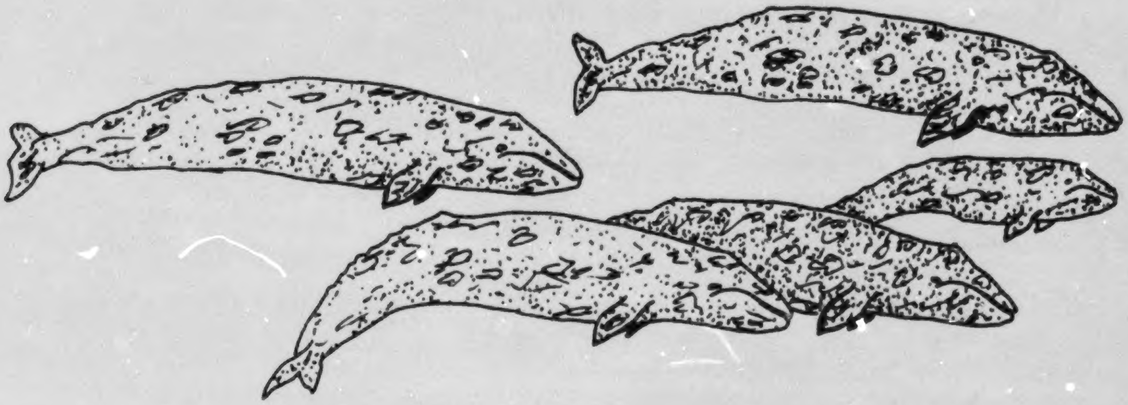


DECEMBER 21

Five days ago our whale left behind most of the small boatloads of whale watchers. Since then she has had fewer noises and shapes about which to worry. Each noise and shape has to be evaluated before she decides whether to continue on her course or to take evasive action. The baby that has been growing within her abdomen now moves strongly. Her rhythmic pattern of breathing, swimming, breathing, swimming, has brought her near the end of her journey. She hears the familiar sounds of the waves breaking on the sand bars at the entrance to Scammon's Lagoon.



Scammon's Lagoon is a large shallow bay. As the tide falls, our whale feels the current from the out-going water. As she swims near the mouth of the Lagoon, she notices many other gray whales. Now swimming with five other females, she waits for the tide to change.



1. What is a lagoon?

2. In what country is Scammon's Lagoon located?

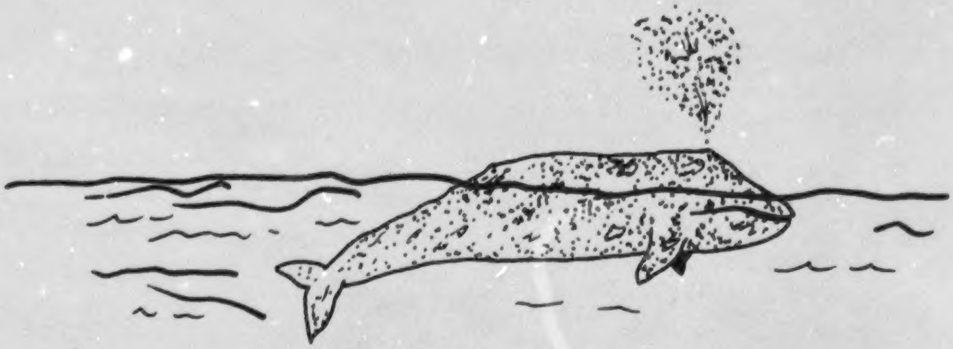
Two and half months have passed since our whale noticed the shortening days in the Arctic north. She has scarcely eaten during this period. She has traveled nearly 7,000 miles to reach the entrance to this lagoon. More whales join the slowly circling group waiting for the tide to change... waiting to enter the quiet waters behind the immense dunes that form the edge of the lagoon.

3. Why do you suppose the whales wait for the tide to change before entering the lagoon?

The waters reverse their direction. Along with her fellows, our whale files through the outer channel between lines of churning water. Aided by the current, she quickly covers the miles and enters the glassy calm of the lagoon. The journey is over.

4. About how many miles has our whale swum since leaving the Arctic?

Morning light finds our whale winding through the narrow tidal channels toward the shallow waters. These shallow back bays have served as a nursery many times before. Her puffs of vapor blend with those from a hundred other females moving through the calm, shallow water.



Our whale spends the next few days exploring the many channels. The activity within her body tells her the time for delivery and motherhood is near.

5. What is one possible reason that gray whales have chosen to bear their offspring in shallow lagoons?

In water barely deep enough to cover her body, our whale delivers her baby. A "mid-wife" whale helps the new female body to the surface for her first gulp of air. The first breath is followed by a second. The second is followed by a third. The most hazardous moment in the small whale's life is past. The newborn calf can soon move to the surface and blow with no assistance.

6. How does a "mid-wife" whale assist in whale births?

The young whale searches for and finds her source of food. For the next two months, she will drink 50 gallons of rich milk each day. During the same period in the nursery lagoon, she will gain 50 pounds per day.

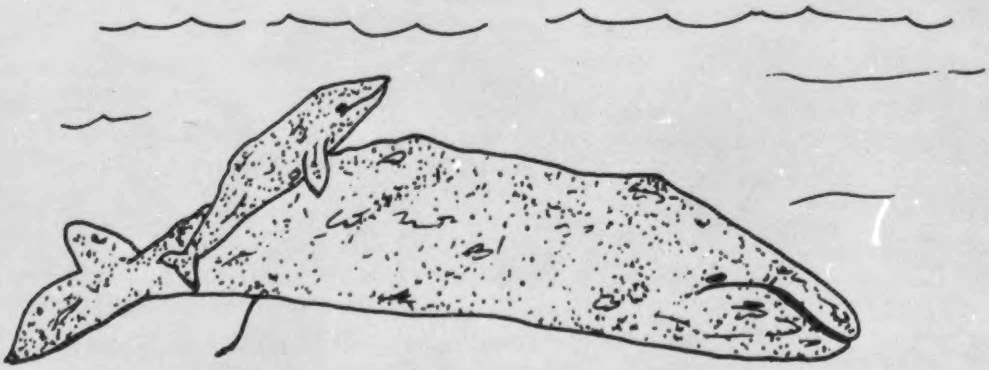
7. A newborn whale calf will average 2,000 pounds at birth. How much will this fourteen foot-long whale weigh at the end of two months? (Hint: two months is 60 days). Please show your work.

8. There is little known about the birth of large whales. Based on observations of dolphins, it is assumed that large whales are born tail first.

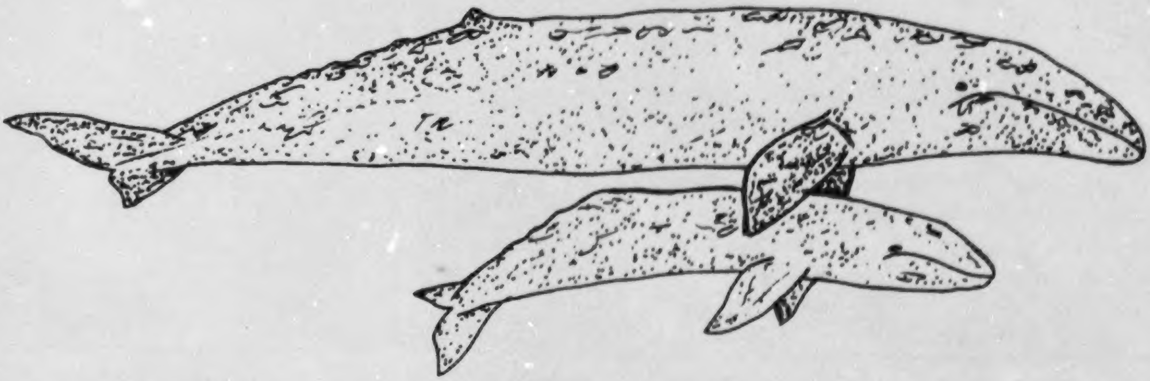
   a. How might being born tail first be an advantage to an air breathing whale?

Recent evidence seems to indicate that gray whales may be born head first.

   b. How might shallow water births and "mid-wife" whales be an advantage for whales born head first?



During its first few weeks of life, our calf gains experience. Her mother guides her repeatedly through the channels of her nursery. She learns to sense the presence of other whales, the sand bars and other obstacles. Slowly she gains independence from her mother. She closely approaches other whales. The relationship between her and her mother strengthens. The currents from her mother's huge tail carry the newborn along. As she grows during the next two months, our newborn whale will be caressed and protected by her mother.



9. Early whalers hunted the California gray whale in the shallow nursery lagoons. Because the whalers were often attacked, they called the gray whale the "devil fish."

   How might the relationship between mother and newborn have contributed to her earning this name?

TEACHER BACKGROUND - The Numbers Game

Twice within the last century man has nearly exterminated the California gray whale. Fortunately for both whale and man, changes in the economics of price, supply and demand caused a shift away from the gray whale. Each shift away allowed the gray whale a period during which the species could regroup. "The Numbers Game" looks at these population fluctuations caused by whaling while emphasizing the comeback potential of the gray whale.

"The Numbers Game" involves modeling population growth using a set of stated assumptions. The model used in this activity is a simplified version of the elaborate computer-based simulations used by biologists to estimate animal populations. Before embarking on the activity spend a few moments discussing the role of modeling in science. Models help us to pull together a number of seemingly diverse observations into a cohesive, meaningful whole. Go over the four assumptions stated in the introduction to the activity. Have your students pass judgement on their reasonableness. 3e prepared to offer any assistance that may be required to help your students complete the data tables and graphs.

Duplicate the activity pages. One set is recommended per student. This activity is best completed by individual students as an in-class or homework assignment. Parts I and II may be assigned on consecutive days. Allow time for a discussion of the "Analysis and Interpretation" sections after your students have completed the activity pages.

KEY

Text questions

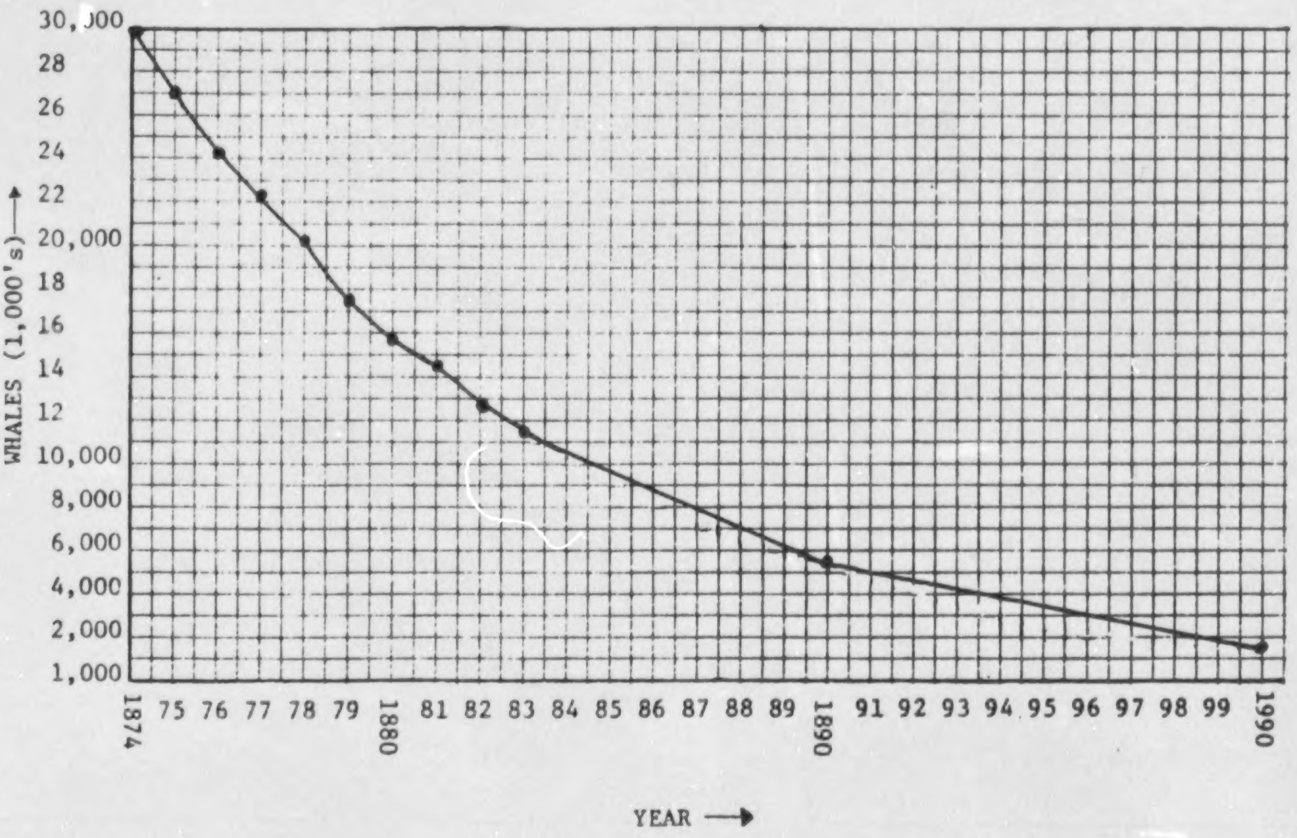
1. If the birth and death rates are the same, the total population size will remain constant from year to year.
2. The last assumption (ie. 10% of the total population is killed each year by whalers) will cause the size of the whale population to decrease.

Part I - The Hunt Is On

1., 2., 3. A completed data chart and graph follow.

Year	# whales at start of year	10% hunted	# whales left at end of year
1874	30,000	3,000	27,000
1875	27,000	2,700	24,300
1876	24,300	2,430	21,870
1877	21,870	2,187	19,683
1878	19,683	1,968	17,715
1879	17,715	1,772	15,943
1880	15,943	1,594	14,349
1881	14,349	1,435	12,914
1882	12,914	1,291	11,623
1883	11,623	1,162	10,461

NUMBER OF GRAY WHALES 1874 - 1900



Analysis and Interpretation:

1. From 1874 to 1883 the gray whale population was decreasing.
2. a. Reasonable estimates for the gray whale population would fall around the following figures:

   1886 *8,500* whales

   1896 *3,000* whales

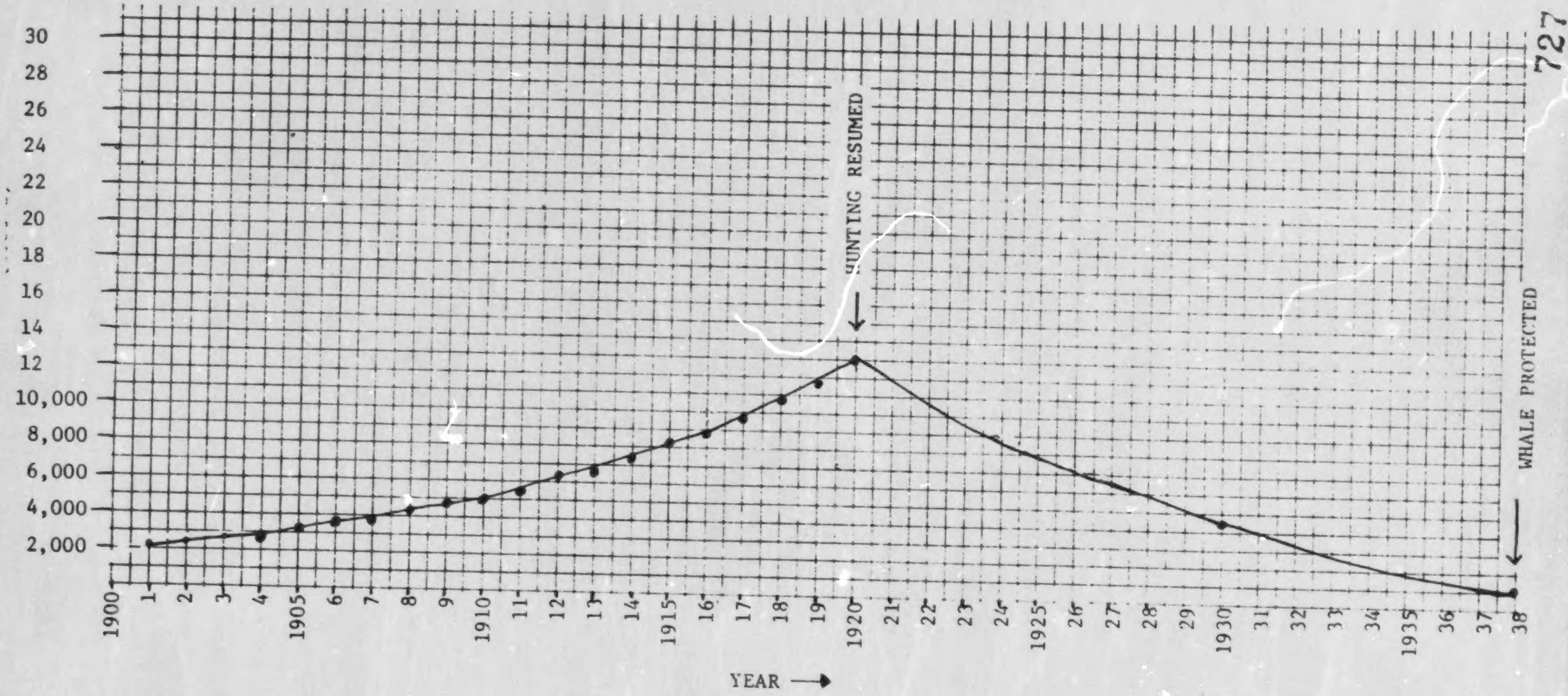
   b. If the trend of the line on the graph continued, the gray whale population would soon be extinct.

Part II - Ups and Downs

1., 2., 3. A completed data chart and graph follow:

Year	# whales at start of year	10%	# whales at end of year
1900	1939	194	2133
1901	2133	213	2346
1902	2346	235	2581
1903	2581	258	2839
1904	2839	284	3123
1905	3123	312	3435
1906	3435	344	3779
1907	3779	378	4157
1908	4157	416	4573
1909	4573	457	5030
1910	5030	503	5533

NUMBER OF GRAY WHALES 1900 - 1920



Analysis and Interpretation:

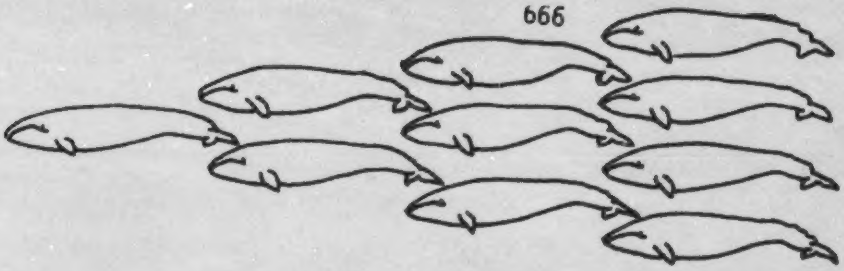
1. From 1900 to 1910, the gray whale population was increasing in number.
2. a. Gray whale hunting resumed in 1920.
    b. Between 1900 and 1920 the gray whale population was increasing in number. This question is repeated here for emphasis.
    c. Predictions may vary. Most of your students will predict that beginning in 1920 the gray whale population will again decrease due to whaling.
3. a. From 1920 to 1938, the gray whale population was decreasing in number.
    b. If the gray whale had not been protected in 1938, the likely fate of the gray whale would have been extermination.
4. a. Three factors that cause death in whales include:
        1. disease
        2. old age
        3. hunting
    b. Births cause the whale population to increase.
    c. The birth rate must have been *less than* / [✓ *equal to*] / *greater than* the death rate. (The correct answer is circled.)
    d. Gray whales eat small bottom dwelling animals. As the gray whale population increases, the numbers of these small animals will *increase* / [✓ *decrease*.] (The correct answer is circled.)
    e. Encourage a discussion of this topic. If no one chooses to limit gray whale population by hunting, you may have to play the devil's advocate. Historically, the gray whale seems to have limited its own population size (or to have had its population limited) at about 30,000 individuals. Some people fear that the seas are now different and that the factors which held whale populations in balance might no longer operate. These people advocate management through hunting rather than allowing the whale populations to build up to high numbers only to have them crash. Basically, we do not have a definitive answer to the gray whale management question. We can be sure, of one thing, however; overhunting is not the answer.

f. From past experience, it appears that the gray whale population has a [✓ *high*] / *low* potential for coming back from near extinction. (The correct answer is circled.)

g. From past experience, it appears that man [✓ *could*] / *could not* hunt gray whales out of existence. (The correct answer is circled.)

KEY WORDS

assumptions
birth rate
bottom dwelling
calculate
commercial value
data points
death rate
esthetic value
estimate
existence
extinction
female
individuals
population
potential
predict
protect
reasonable
resumed
species
stable
ultimate



THE NUMBERS GAME

Our whale has successfully birthed her calf. How many calves are born each year? How many need to be born to keep the population size the same? How many to allow the whale population to increase? The following activity will help to answer some of these questions.

Before we begin, we need to make some assumptions. An assumption is a statement we will suppose to be true. We will assume that:

- 50% (half) of the gray whale population is female (does this seem reasonable to you?).
- Each female produces a calf every other year (gray whales remain with their young for 20 months, so this seems reasonable).
- 25% of the population die each year from disease and old age (this seems reasonable).
- 10% of the total population is killed each year by whalers (this number is based on historical records).

Under our assumptions, the births and the deaths would balance. In other words, the same number of whales die as are born.

1. If the birth and death rates are the same, what will happen to the total population size from year to year?

2. The second assumption causes the population size to increase. How will the last assumption change the size of the whale population?

Part I - The Hunt Is On.

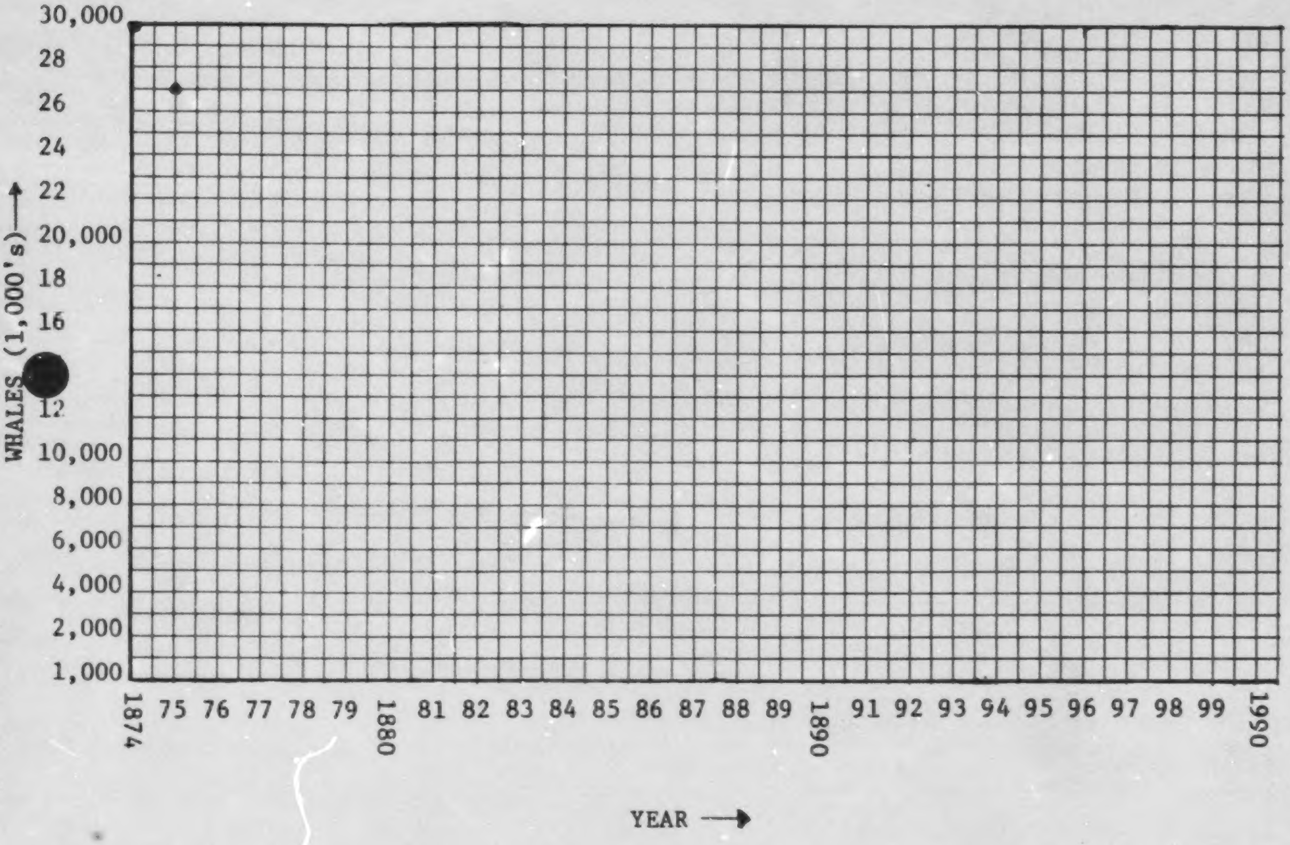
1. Whalers sailing from New England began to heavily hunt the gray whale about 1850. In 1874, Captain Charles M. Scammon published an account of Pacific whaling. He estimated the gray whale population at about 30,000 individuals. We will use this number as a starting point. Complete the following table:

Year	# whales at start of year	10% killed (0.10 times # at start)	# whales at end of year (start minus 10%)
1874	30,000	3,000	27,000
1875	27,000		
1876			
1877			
1878			
1879			
1880			
1881			
1882			
1883			

2. Use the figures you calculated in the above table to complete the graph on the next page. This is easy. Move across the year line until you find 1875. Now move straight up the page until you are on the same line as the number 27,000. (27,000 is the number of whales at the start of 1975.) Make a dot at this point. Do the same for each year until 1883.

3. Now connect the dots (data points) from 1874 to 1883 with a smooth line.

NUMBER OF GRAY WHALES 1874 - 1900



Analysis and Interpretation:

1. What was happening to the gray whale population from 1874 to 1883?

2. The population in 1890 was estimated to be 5,559 whales. In 1900 it was estimated to be 1,939 whales. Add these two figures to your graph. Use a smooth line to connect these years to the smooth line you have drawn connecting 1874 to 1883.

   a. Use your graph to estimate the whale population in 1886 and in 1896. Record your estimates in the spaces below:

      1886 _____________ whales

      1896 _____________ whales

   b. If the line on the graph were continued, what would be the ultimate fate of the gray whale population?

Part II - Ups and Downs

By 1900 the gray whale became hard to find. The whalers turned to other species of whales. The gray whale had a chance to rebuild its population. The 1900 population was estimated to be 1,939 whales. Once whaling stopped, births exceeded deaths by about 10% per year. Complete the following table:

Year	# whales at start of year	10% added (0.10 times # at start)	# whales at end of Year (start plus 10%)
1900	1939	194	2133
1901	2133		
1902			
1903			
1904			
1905			
1906			
1907			
1908			
1909			
1910			

2. Use the figures you calculated in the above table to complete the graph on the next page. This is easy. Follow the procedure you used in Part I. Plot each year from 1900 to 1910.

3. Now connect the dots (data points) from 1900 to 1910 with a smooth line.

Analysis and Interpretation:

1. What was happening to the gray whale population from 1900 to 1910?

2. The population in 1920 was estimated to be 13,047 whales. In 1920 gray whale hunting resumed. Add the 1920 population estimates to your graph. Continue your smooth line to connect the 1920 estimate to your estimates from 1900 to 1910.

   a. When did gray whale hunting resume?

   b. What was happening to the gray whale population between 1900 and 1920?

   c. What do you predict will happen to the gray whale population beginning in 1920?

3. The gray whale population in 1930 was estimated to be 4,549 individuals. In 1938, the population was estimated to be 1,957. In 1938, the gray whale was protected from further hunting. Add the population estimates from 1930 and 1938 to your graph. Use a smooth line to connect these years to the smooth line you have drawn to connect 1900 to 1920.

   a. What was happening to the gray whale population from 1920 to 1938?

   b. If the gray whale had not been protected in 1938, what would have been the likely fate of the gray whale?

4. Once the gray whales were protected, they were able to again rebuild their population. By 1961 the population had reached about 6,000 individuals. By 1971 over 10,000 whales were estimated. By 1981, the population was estimated at over 28,000. Scammon's estimated a before hunting population of 30,000 individuals. The 1982 population estimate is about 31,000.

   a. The death rate causes the whale population to decrease. What are three factors that cause death in whales?

      1.

      2.

      3.

   b. What causes the whale population to increase?

   c. Historically, the gray whale population remained stable at about 30,000 individuals. The birth rate must have been less than / equal to / greater than the death rate. (Circle the correct answer.)

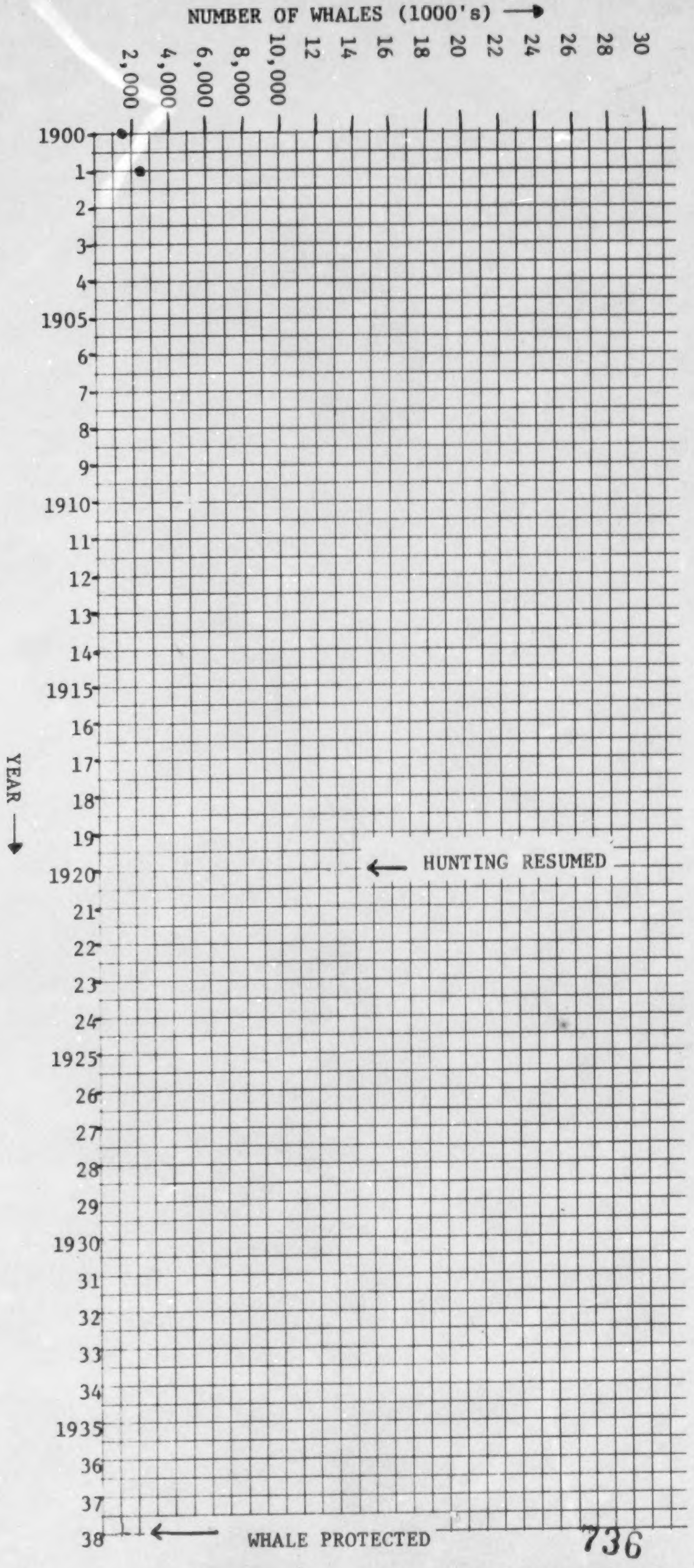
   d. Gray whales eat small bottom dwelling animals. As the gray whale population increases, the numbers of these small animals will increase / decrease. (Circle the correct the answer.)

   e. Some people feel that the gray whale population is now in danger of eating itself into trouble. They say that the whale population is too large for its food supply. These people feel that limited hunting of gray whales should occur. Others argue that the commercial value of gray whales is less than their esthetic value to whale watchers. This group favors no hunting.
   feel that limited hunting of gray whales should occur. Others argue that the commercial value of gray whales is less than their esthetic value to whale watchers. This group favors no hunting.

   What is your position in this argument? Why?

   f. From past experience, it appears that the gray whale population has a high / low potential for coming back from near extinction. (Circle the correct answer.)

   g. From past experience, it appears that man could / could not hunt gray whales out of existence. (Circle the correct answer.)



NUMBER OF GRAY WHALES 1900 - 1920

TEACHER BACKGROUND - February 21 and The Electronic Whale

A good portion of the gray whale's annual migration remains somewhat of a mystery to scientists. "February 21" sees our gray whale and her calf leave the nursery grounds of Scammon's lagoon and enter the "mystery" portion of the migration. This reading serves to return our gray whale to the summer feeding grounds and to complete the annual cycle. There is considerable debate regarding the north-ward path of the migration. "The Electronic Whale" is a computer simulation of the entire southern migration of the gray whale. The simulation serves as an effective, and enjoyable, summary activity to conclude our look at the greatest migration known to man.

The computer simulation was originally developed by Community Educational Resources of the San Diego County (California) Department of Education. The version included here was written by Michael Schuyler for use with Apple II computer systems. The simulation requires a computer terminal and television monitor. A little exploration within your district will likely reveal the presense of a computer which you could utilize for this activity. Stores dealing in computers are sometimes willing to loan terminals to schools. Your entire class may participate in the simulation by connecting the terminal directly to a television monitor. You may also wish to provide your students with opportunities to later play the simulation individually or in small groups. A detailed program description and sample run are included below. A printout of the computer program follows the "Key Words" section. Any master computer disk is available for duplication from the Marine Science Project: FOR SEA; 1303 Sylvan Way; Bremerton, WA 98310.

Overview of Simulation

The California gray whale computer simulation allows your students an opportunity to select real life variables which influence the progress of migrating gray whales from their feeding grounds in the Arctic, to their summer calving grounds in Mexico. Each run of the program allows the individual student to select a starting location and a final destination. These choices help point out the range where these animals may be found. The whale is programmed to encounter a variety of natural phenomena such as a Gulf of Alaska storm where the student can control the intensity of the weather, a random food encounter to explain what is thought to happen during such an event, and a random killer whale encounter with the potential for attack and destruction of the whale. When the simulation whale reaches the Southern California area, the student will need to choose whether to allow the whale to swim inside the Channel Islands and experience potential harassment by whale watchers, or to swim outside the islands and be free of such disturbance. The object of the simulation is to get the whale to a lagoon before the allotted time is up.

How The Model Works

Students select one of six starting locations, then one of four destinations. The distance required to travel is calculated within the program. The student then determines an appropriate swimming speed. The speed is required to fall between four and twelve kilometers per hour. Choices which are lower are too slow and a statement is printed which explains and instructs the student to make another choice. Speeds greater than twelve are too fast and a brief statement is printed. The student is then instructed to make another choice. When a speed between four and twelve is selected, the student is reinforced and allowed to continue. The computer then begins to calculate daily progress by multiplying the student's speed input times 24 hours. Most scientists agree that a whale will swim continuously in order to arrive at the lagoon on time.

A daily progress loop is then entered where the program checks to see if the distance traveled is sufficient to have arrived at the lagoon; or whether the time has run out before the destination was reached. Along the way, various encounters are possible. The encounters are generated randomly within the program or are dependent on the specific location of the whale at that moment.

One distance dependent item is a storm in the Gulf of Alaska. The student will select the severity of the weather by choosing a number between one and ten. These are related to the Weather Services use of Beaufort wind scale factors. The severity of the weather will influence the progress which the whale is able to accomplish in a day. Smooth weather has no effect and progress remains unchanged. Mild storms influence the distance traveled per day by slowing the animal somewhat, while severe weather hampers progress by slowing the animal and reducing the hours spent swimming per day. Printouts are given to the students reflecting the choice of conditions.

Within the program are two randomly generated occurrences--a killer whale encounter and a potential food encounter. There is no control established over when this could happen since both events are probable anytime in real life. If killer whales are encountered, the student must make a decision on how to react to their presence. In 20 percent of the cases, the killer whales will attack and then one-third of the time the animals' attack will be successful in destroying the gray whale. Other times, the gray whale will escape with scars as in real life situations. This portion demonstrates what is believed to happen during the encounters with the only other predator besides man.

An encounter with squid is also randomly generated by the program. They are potential food for whales, and it is not understood fully if a whale would use the opportunity to feed for a short time. Most scientists agree that whales feed very little during migration, but unusual behavior has been reported in areas where squid are known to occur.

A decision must be made by the student when the whale reaches Point Conception. The student may elect to have the whale swim outside the Channel Islands or allow it to go inside. If the student chooses outside, nothing happens and the whale progresses at the same rate. A short printout explains what occurred. If the student chooses to swim the whale inside the islands, the whale will encounter whale watching boats. Here the student will determine which technique of whale watching is preferred. Depending on the choice, the whale will progress normally or will be slowed by the need to use evasive behavior to keep away from the disturbance created by the observers. This encounter points out the issue of harassment and the need for the use of proper techniques when whale watching from boats.

The object of the simulation is to get the whale to the lagoon before the time allowed is gone. A 90-day limit is imposed representing the three-month migration. Successful completion is congratulated, and unsuccessful completion generates a suitable remark. The student can then elect to replay the simulation without signing off and restarting.

Assumptions

The computer program is constructed from the following assumptions:

1. Gray whales start from one of six locations. Actually, this is to represent the large area where whales may start from. Many animals go

all the way north, while others only go to British Columbia or somewhere in between.

2. Gray whales only go to four principle lagoons in Mexico. They may be again distributed along the range and many lesser lagoons exist which contain animals.

3. Gray whales swim for 24 hours per day. It is believed that they swim continuously; maybe faster sometimes and slower other times. Occasionally one will be observed sleeping near shore, but this is the exception rather than the rule.

4. Gray whales are adversely affected by severe storms. No one really knows what happens for sure. Cetaceans have been seen struggling during severe weather when the surface was covered with foam. Foam does not allow the animal to breathe or support its weight.

5. Gray whales are of interest to killer whales 20 percent of the time, and killer whales are successful in 33 percent of their attacks. These percentages are derived from the work of Rice and Wolman who studied gray whales. No one knows the success rate of these attacks for sure.

6. Gray whales sometimes stop to investigate potential food.

7. Gray whales are slowed by whale watching harassment. Since experience has shown that improper techniques can disrupt whales, slow them, and change their course, formulas were estimated to quantify the effect. The more severe the encounter, the longer the delay in reaching the lagoon.

8. Gray whales must reach the lagoon to be successful. This is really not true as animals have given birth and mated all along the migration route. However, to have a simulation goal, successfully reaching the lagoon within the 90-day period was selected.

Sample Printout

A sample print out is included to show the program format.

```
GET-WHALE
RUN
WHALE

WELCOME TO THE GRAY WHALE MIGRATION GAME.  THE OBJECT OF THIS LEARNING GAME IS TO GET 'YOUR
WHALE' FROM A STARTING POINT TO A FINAL DESTINATION BEFORE THE TIME RUNS OUT.  ALONG THE
WAY YOU WILL ENCOUNTER REAL LIFE 'PROBLEMS' FOR YOUR WHALE.  BY TESTING THE CHOICES
AVAILABLE, YOU WILL BE ABLE TO LEARN HOW THESE ENCOUNTERS INFLUENCE THE WHALE AS IT MOVES
DOWN THE COAST.

WHEN ASKED FOR A RESPONSE, PLEASE ENTER YOUR CHOICE CAREFULLY, THEN DEPRESS THE CARRIAGE
RETURN KEY (ON THE RIGHT).  GOOD LUCK.

THE FOLLOWING PLACED ARE THE POSSIBLE STARTING LOCATIONS: SEE THE STUDENT HANDBOOK FOR
THEIR RELATIVE LOCATIONS.
1 - PT. BARROW, ALASKA
2 - THE BERING STRAIT
3 - ST. LAWRENCE ISLAND, BERING SEA
4 - UNIMAK PASS, ALEUTIAN ISLANDS
5 - QUEEN CHARLOTTE ISLANDS, CANADA
6 - VANCOUVER ISLAND, BRITISH COLUMBIA, CANADA

PLEASE SELECT A NUMBER WHICH REPRESENTS YOUR CHOICE OF STARTING LOCATION.

? 6

THE FOLLOWING ARE YOUR CHOICES OF A FINAL DESTINATION, CONSULT YOUR STUDENT HANDBOOK.

              DESTINATION                    DISTANCE FROM SAN DIEGO (IN KILOMETERS)

1 - SCAMMON'S AND GUERRERO NEGRO LAGOONS,                  650
       BAJA CALIFORNIA, MEXICO
2 - SAN IGNACIO LAGOON, BAJA CALIFORNIA,                   800
       MEXICO
3 - MAGDELENA BAY, BAJA CALIFORNIA,                        1100
       MEXICO
4 - YAVAROS, SONORA, MEXICO                                1800

CHOOSE A FINAL DESTINATION, BY NUMBER

? 2

WHAT WILL BE YOUR WHALE'S NORMAL SWIMMING SPEED, IN KILOMETERS PER HOUR?

? 11

GOOD CHOICE!  YOUR WHALE WILL PROCEED AT 11 KILOMETERS PER HOUR.

YOU HAVE ENCOUNTERED A GROUP OF KILLER WHALES.  THESE ANIMALS ARE POTENTIAL PREDITORS
AND THEIR PRESENCE DISTURBS YOUR WHALE.  HOW DO YOU CHOOSE TO REACT TO THEM?

1 - TRY TO SWIM AWAY QUICKLY

2 - STOP ANY SOUND PRODUCTION (VOCALIZATION);
    SWIM AWAY IN AN EVASIVE MANNER TO THE KELP BEDS.  GENERAL AVOIDANCE BEHAVIORS.

3 - NO CHANGE IN BEHAVIOR, JUST CONTINUE IN THE SAME MANNER, IGNORING THEIR PRESENCE.


WHICH METHOD WILL YOUR WHALE FOLLOW:  1, 2, OR 3?

? 3

THE KILLER WHALES ARE NOT INTERESTED AT THIS TIME.  YOUR WHALE HAS ESCAPED.
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YOUR WHALE HAS ENCOUNTERED A CONCENTRATION OF SQUID.  THIS COULD BE A POTENTIAL FOOD
SOURCE.  HOW DO YOU CHOOSE TO REACT?
1 = INVESTIGATE    2 = IGNORE IT

? 2
DAYS = 9    DISTANCE = 2376    FROM PT. BARROW, ALASKA

STORM ENCOUNTERED IN THE GULF OF ALASKA.  PLEASE CHOOSE THE SEVERITY OF THE WEATHER FROM
1 TO 10.

? 3
YOUR CHOICE - LARGE WAVELETS, OCCASIONAL FOAM CREST

NOT A BAD STORM, CONTINUE AT SAME RATE OUT OF STORM, CONTINUE JOURNEY AT STANDARD RATE.

THE DISTANCE TRAVELLED SO FAR = 2904  KILOMETERS
DAYS TRAVELLED = 11

DAYS = 20   DISTANCE = 5280   FROM PT. BARROW, ALASKA

YOUR WHALE HAS ARRIVED AT PT. CONCEPTION, NORTH OF SANTA BARBARA, CALIFORNIA WHERE YOU
MUST CHOOSE WHETHER YOUR WHALE WILL SWIM OUTISDE THE CHANNEL ISLANDS OR CONTINUE
ALONG THE COAST.  WHAT WILL YOUR CHOICE BE?
   INSIDE = 1       OUTSIDE = 2       PLEASE CHOOSE

? 1

YOUR WHALE IS OFF THE SOUTHERN CALIFORNIA COAST MOVING PAST THE POPULATION CENTERS OF
LOS ANGELES AND SAN DIEGO WHERE MANY PEOPLE ENJOY WATCHING THE WHALE MIGRATION FROM
BOATS.
CHOOSE A METHOD OF WHALEWATCHING
1 - SLOW APPROACH FROM THE REAR OF THE ANIMALS AT THEIR SPEED, GENTLY MOVING CLOSER,
    LEAVING THE MOTOR RUN AT A CONSTANT SPEED.

2 - MORE RAPID APPROACH FROM BEHIND THE ANIMALS, SOME RACING OF THE ENGINE TO CATCH THEM
    QUICKLY, THEN SLOWING TO STAY WITH THEM LONGER

3 - RACING APPROACH TO GET TO THE WHALES QUICKLY THEN SLOWING DOWN TO STAY WITH THEM.
    IF THEY MOVE AWAY, RACE OVER TO THEM AGAIN TO GET AS CLOSE AS POSSIBLE.

YOUR CHOICE OF 1, 2, 3  IS

? 1

VERY EFFECTIVE WHALEWATCHING, CAUSED NO DISTURBANCE TO THE WHALE AND THEREFORE DID NOT
SLOW IT DOWN.  THE ANIMAL DID NOT USE AVOIDANCE BEHAVIORS, OR CHANGE ITS SPEED, OR CHANGE
ITS DIRECTION.  THIS METHOD IS USED SUCCESSFULLY TO OBSERVE THE WHALES BY HUNDREDS OF
SKILLED OPERATORS YEARLY.


LEAVING THE POPULATION CENTERS, AND HARASSMENT DISTANCE IS NOW 6864  KILOMETERS,
ELAPSED TIME IS 26  DAYS
DAYS = 30    DISTANCE = 7920    FROM PT. BARROW, ALASKA

CONGRATULATIONS, YOUR WHALE HAS ARRIVED ON TIME.
YOU WIN  !

                             .
           'LE.  ...  .....E*W'
            *WHALE*WHALE*WHALE
              *WHALE*WHALE*W'
                 WHALE*WHA'
                  *WHAL'                  .*ALE*WHALE*.
                   E*W'               .*ALE*WHALE*WHALE*W.
                  .ALE             .*LE*WHALE*WHALE*WHALE*W.
                  WHAL.        ..*E*WHALE*WHALE*WHALE*WHALE*
                 LE*WHAL....ALE*WHALE*WHALE*WHALE*WHALE*WHAL
                WHALE*WHALE*WHALE*WHALE*WHALE*WHALE*WHALE*WH
                E*WHALE*WHALE*WHALE*WHALE*WHALE*WHALE*WHALE*
                'LE*WHALE*WHALE*WHALE*WHALE*WHALE*WHALE*WHA'
                 'ALE*WHALE*WHALE*WHALE*WHALE*WHALE*WHALE*'
                  'HALE*WHALE*WHALE*WHALE*WHALE*WH''''''''
                    ''ALE*WHALE*WHALE*WHALE*WHALE*WHALE*W
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WOULD YOU LIKE TO TRY AGAIN   YES = 1,  NO = 2

? 2

THANK YOU FOR PLAYING THE GRAY WHALE MIGRATION LEARNING GAME.

A COMMUNITY EDUCATIONAL RESOURCES PRODUCTION

DEPARTMENT OF EDUCATION, SAN DIEGO COUNTY
                                     *.
                                     '**.
                                      '***.
     #####   #####   #####             '****.
     ##      ##      ##  #              '*****.
     ##      ####    #####              '******
     ##      ##      ## #                *****
     #####   #####   ##  #              '****
                                        ****
            COMMUNITY                  '***
           EDUCATIONAL                 ***
            RESOURCES                 '**
                                      **
                                     '*
                                     *
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Duplicate the text and activity pages. One set is recommended per student. "February 21" is best accomplished by individual students as homework or an in-class assignment. "The Electronic Whale" is ideally accomplished as a whole class activity followed by simulation runs by individual student. Use these activities to tie together and complete our look at a year in the life of the California gray whale. Hopefully, it has been an interesting and profitable experience.

The California gray whale is the only whale population that, following severe depletion, has recovered to near-original numbers. We cannot be optimistic about its future, however. The new Baja California Highway has made some of the whale's calving lagoons readily accessible to small boats hauled overland. Industrialization and pollution of the lagoons will undoubtedly accelerate as the human population grows. In addition, proposed oil drilling on or adjacent to the lagoons poses another threat to the future of the California gray whale, the great mammalian migrator. We can only hope that the education we provide today to tomorrow's decision-makers will enable them to make ecologically sound choices.

KEY

February 21

1. The newborn whales will spend their first summer in the Arctic.
2. a. The answers will vary. Use this question as a springboard for a discussion of the scientific data gathering process.
   b. The equipment and materials needed are determined by the design of the research study.

The Electronic Whale

1. Summer food supply is the greatest at locations 1, 2, and 3 (Pt. Barrow, Bering Strait and Bering Sea).
2. Because of the warm, still waters newborn whales have the greatest chance of survival at locations 9, 10, 11, and 12 (Scammon's and Guerrero Negro Lagoons, San Ignacio Lagoon, Magdalena Bay, and Yavaros).

KEY WORDS

annual
assumptions
blubber
calf
carcasses
computer
computer terminal
encounter
extensive
ice floes
incredible
lagoon
migration
models
nursery
nurslings
phytoplankton
predators
programmed
remarkable
responses
simulation
solution
surveys
technology
zooplankton

PRINTOUT OF THE COMPLETE PROGRAM

```
10 REM  GRAY WHALE MIGRATION GAME
20 REM  MODIFIED FOR APPLE II
30 PRINT "WELCOME TO THE GRAY WHALE MIGRATION"
40 PRINT "GAME. THE OBJECT OF THIS LEARNING"
50 PRINT "GAME IS TO GET 'YOUR WHALE' FROM A"
60 PRINT "STARTING POINT TO A FINAL DESTINATION"
70 PRINT "BEFORE THE TIME RUNS OUT. ALONG THE"
80 PRINT "WAY YOU WILL ENCOUNTER REAL LIFE"
90 PRINT "PROBLEMS FOR YOUR WHALE. BY TESTING"
100 PRINT "THE CHOICES AVAILABLE YOU WILL BE"
110 PRINT "ABLE TO LEARN HOW THESE ENCOUNTERS"
120 PRINT "INFLUENCE THE WHALES AS THEY MOVE"
130 PRINT "DOWN THE COAST."
140 PRINT
150 PRINT "WHEN ASKED FOR A RESPONSE PLEASE"
160 PRINT "ENTER YOUR CHOICE CAREFULLY THEN"
170 PRINT "PRESS THE RETURN KEY. GOOD LUCK!"
180 REM  CHOOSING STARTING LOCATION AND A FINAL DESTINATION
190 PRINT
200 PRINT "THE FOLLOWING PLACES ARE THE POSSIBLE"
210 PRINT "STARTING LOCATIONS. SEE THE STUDENT"
220 PRINT "HANDBOOK FOR THEIR RELATIVE LOCATIONS."
230 PRINT
240 GOSUB 4910
250 PRINT "1 - PT. BARROW ALASKA"
260 PRINT "2 - THE BERING STRAIT"
270 PRINT "3 - ST. LAWRENCE ISLAND - BERING SEA"
280 PRINT "4 - UNIMAK PASS - ALEUTIAN ISLANDS"
290 PRINT "5 - QUEEN CHARLOTTE ISLANDS - CANADA"
300 PRINT "6 - VANCOUVER ISLAND -B.C.- CANADA"
310 PRINT
320 INPUT "PLEASE SELECT STARTING LOCATION: ";D1
330 R1 = 0
340 IF D1 = 1 THEN 440
350 IF D1 = 2 THEN 460
360 IF D1 = 3 THEN 480
370 IF D1 = 4 THEN 500
380 IF D1 = 5 THEN 520
390 IF D1 = 6 THEN 540
400 PRINT
410 PRINT "I COULD NOT FIND YOUR CHOICE: REENTER"
420 GOTO 320
430 REM  ASSIGN DISTANCE VALUE TO START
440 D1 = 0
450 GOTO 550
460 D1 = 800
470 GOTO 550
480 D1 = 960
490 GOTO 550
500 D1 = 2000
510 GOTO 550
520 D1 = 3920
530 GOTO 550
540 D1 = 4720
550 IF R1 < 0 THEN 2170
560 PRINT
570 PRINT "THE FOLLOWING ARE YOUR CHOICES OF"
580 PRINT "A FINAL DESTINATION - CONSULT"
590 PRINT "YOUR STUDENT HANDBOOK."
600 PRINT
610 PRINT "DESTINATION              DISTANCE FROM"
620 PRINT "                           SAN DIEGO"
630 PRINT
640 PRINT "1 - GUERRERO NEGRO LAGOONS"
650 PRINT "     BAJA CALIFORNIA              650"
660 PRINT "2 - SAN IGNACIO LAGOON"
670 PRINT "     BAJA CALIFORNIA              800"
680 PRINT "3 - MAGDALENA BAY"
690 PRINT "     BAJA CALIFORNIA             1100"
700 PRINT "4 - YAVAROS SONORA"
710 PRINT "     MEXICO                      1800"
720 PRINT
730 INPUT "CHOOSE A FINAL DESTINATION BY NUMBER: ";D2
740 PRINT
750 IF D2 = 1 THEN 830
760 IF D2 = 2 THEN 850
770 IF D2 = 3 THEN 870
780 IF D2 = 4 THEN 890
790 PRINT
800 PRINT "I WAS UNABLE TO FIND YOUR CHOICE:"
810 GOTO 730
820 REM  ASSIGN DISTANCE VALUES TO DESTINATION
830 D2 = 7840
840 GOTO 900
850 D2 = 8000
860 GOTO 900
870 D2 = 8320
880 GOTO 900
890 D2 = 9040
900 D3 = D2 - D1
910 REM  SWIMMING SPEED
920 PRINT
930 PRINT "WHAT WILL BE YOUR WHALE'S NORMAL"
940 PRINT "SWIMMING SPEED IN KILOMETERS PER"
950 INPUT "PER HOUR? ";S
960 IF S < 4 THEN 1070
970 IF S < 12 THEN 1170
980 PRINT
990 PRINT "YOUR CHOICE OF SWIMMING SPEED IS"
1000 PRINT "TOO FAST. GRAY WHALES CANNOT SWIM THAT"
```

```
1010  PRINT "FAST OR THEY WILL OVERHEAT. BECAUSE"
1020  PRINT "OF THE INSULATING PROPERTY OF BLUBBER"
1030  PRINT "THIS COULD CAUSE DEATH TO THE ANIMAL."
1040  PRINT "PLEASE CHOOSE AGAIN."
1050  PRINT
1060  GOTO 930
1070  PRINT
1080  PRINT "YOU ARE MOVING TOO SLOWLY. YOUR WHALE"
1090  PRINT "HAS ";D3;" KILOMETERS TO GO IN ONLY"
1100  PRINT "90 DAYS. AT THE RATE OF ";S;" KILOMETERS"
1110  PRINT "PER HOUR YOUR WHALE WILL BE ABLE TO"
1120  PRINT "SWIM ";(S * 24) * 90;" KILOMETERS"
1130  PRINT
1140  PRINT "PLEASE CHOOSE AGAIN"
1150  PRINT
1160  GOTO 930
1170  PRINT
1180  PRINT "GOOD CHOICE! YOUR WHALE WILL PROCEED"
1190  PRINT "AT ";S;" KILOMETERS PER HOUR."
1200  PRINT
1210  REM  MIGRATION CLOCK
1220 T = 0
1230 C = 0
1240 T2 = 24
1250 K1 = 0
1260 D = 0
1270 F1 = 0
1280 F = 0
1290 G = 0
1300  REM  DAYS AVAILABLE TO REACH DESTINATION =90
1310 T3 = 90
1320  FOR X = 1 TO 100
1330  REM  LISTING EACH TEN DAY PROGRESS
1340 G = G + 1
1350  IF G < 10 THEN 1410
1360  PRINT "DAYS = ";T
1370  PRINT "DISTANCE = ";D
1380  PRINT "FROM PT. BARROW ALASKA"
1390  PRINT : GOSUB 4910
1400 G = 0
1410  REM  ARRIVAL CHECK
1420  IF D > D2 THEN 2180
1430  IF T > T3 THEN 2230
1440  REM  ENCOUNTER A STORM BETWEEN 2500 AND 2900 KM
1450  IF D < 2500 THEN 1480
1460  IF D > 2900 THEN 1480
1470  GOSUB 2270
1480  REM  RANDOM KILLER WHALE ENCOUNTER
1490 K =  INT (50 *  RND (1)) + 1
1500  IF K < 3 THEN 1520
1510  GOTO 1550
1520  GOSUB 3830
1530  PRINT
1540 K1 = K1 + 1
1550  REM  RANDOM ENCOUNTER WITH FOOD SOURCE
1560 F =  INT (50 *  RND (1)) + 1
1570  IF F1 > 0 THEN 1840
1580  IF F > 3 THEN 1840
1590  PRINT
1600  PRINT "YOUR WHALE HAS ENCOUNTERED A"
1610  PRINT "CONCENTRATION OF SQUID. THIS"
1620  PRINT "COULD BE A POTENTIAL FOOD SOURCE."
1630  PRINT "HOW DO YOU CHOOSE TO REACT?"
1640  PRINT : PRINT "1 - INVESTIGATE"
1650  PRINT "2 - IGNORE"
1660  PRINT
1670  INPUT F1
1680  IF F1 = 2 THEN 1840
1690  PRINT
1700  PRINT "IT IS NOT KNOWN FOR CERTAIN WHETHER"
1710  PRINT "YOUR WHALE WILL FEED. GRAY WHALES"
1720  PRINT "HAVE BEEN SEEN SWIMMING IN AREAS"
1730  PRINT "WHERE SQUID HAVE BEEN REPORTED TO"
1740  PRINT "BE CONCENTRATED. HOWEVER AN ENCOUNTER"
1750  PRINT "TO INVESTIGATE WILL DELAY YOUR WHALE"
1760  PRINT "SEVERAL HOURS AND HE MAY EVEN SNACK."
1770  PRINT "IT IS THOUGHT THAT GREY WHALES DO NOT"
1780  PRINT "FEED MUCH DURING THEIR ANNUAL"
1790  PRINT "MIGRATION. MOST SCIENTISTS AGREE THAT"
1800  PRINT "THEY FEED ONLY DURING THE FOUR"
1810  PRINT "MONTHS IN THE BERING AND CHUKCHI SEAS."
1820  PRINT : GOSUB 4910
1830 F1 = 1
1840  REM  CHECK HOW CLOSE TO POPULATION CENTERS
1850  IF D < 6800 THEN 2140
1860  IF D > 7200 THEN 2140
1870  IF C > 0 THEN 2140
1880  PRINT
1890  PRINT "YOUR WHALE HAS ARRIVED AT"
1900  PRINT "POINT CONCEPTION"
1910  PRINT "NORTH OF SANTA BARBARA CALIFORNIA
1920  PRINT "WHERE YOU MUST CHOOSE WHETHER YOUR"
1930  PRINT "WHALE WILL SWIM OUTSIDE THE CHANNEL"
1940  PRINT "ISLANDS OR CONTINUE ALONG THE COAST."
1950  PRINT "WHAT WILL YOUR CHOICE BE?"
1960  PRINT
1970  PRINT "INSIDE - 1  OUTSIDE - 2"
1980  PRINT
1990  INPUT "PLEASE CHOOSE ";C
2000  IF C = 1 THEN 2120
```

```
2010 D = S * T2 + D
2020 T = T + 1
2030  IF D < 7200 THEN 2010
2040  PRINT
2050  PRINT "LEAVING THE CHANNEL ISLANDS AND"
2060  PRINT "ARRIVING AT THE NORTHERN EDGE OF"
2070  PRINT "BAJA CALIFORNIA THIS OUTSIDE ROUTE"
2080  PRINT "HAS BEEN FREE OF WHALE WATCHING AND"
2090  PRINT "THE POSSIBLE HARASSMENT FROM THAT"
2100  PRINT "ACTIVITY."
2110  GOTO 2140
2120  REM  WHALEWATCHING SUBROUTINE
2130  GOSUB 3120
2140  REM  DAILY PROGRESS REPORT
2150 D = S * T2 + D
2160 T = T + 1
2170  NEXT X
2180  PRINT
2190  PRINT "CONGRATULATIONS! YOUR WHALE HAS "
2200  PRINT "ARRIVED ON TIME. YOU WIN!"
2210  GOSUB 4610
2220  GOTO 4540
2230  PRINT
2240  PRINT "TOO BAD. THE TIME IS UP. YOUR WHALE"
2250  PRINT "HAS ARRIVED TOO LATE. YOU LOSE!"
2260  GOTO 4540
2270  REM  WEATHER SUBROUTINE
2280  PRINT
2290  PRINT "STORM ENCOUNTERED IN THE GULF OF ALASKA"
2300  PRINT "PLEASE CHOOSE THE SEVERITY OF THE"
2310  PRINT "WEATHER FROM 1 TO 10"
2320  PRINT
2330  INPUT B
2340  REM  WEATHER EQUATED TO BEAUFORT WIND FORCE AND SEA
2350  IF B = 1 THEN 2470
2360  IF B = 2 THEN 2490
2370  IF B = 3 THEN 2520
2380  IF B = 4 THEN 2550
2390  IF B = 5 THEN 2580
2400  IF B = 6 THEN 2600
2410  IF B = 7 THEN 2630
2420  IF B = 8 THEN 2660
2430  IF B = 9 THEN 2690
2440  IF B = 10 THEN 2720
2450  PRINT "CHOOSE A NUMBER LESS THAN 11"
2460  GOTO 2300
2470  PRINT "YOUR CHOICE: SEA SMOOTH AND MIRROR LIKE"
2480  GOTO 2710
2490  PRINT "YOUR CHOICE: SCALE-LIKE RIPPLES ON"
2500  PRINT "THE WATER. NO FOAM CRESTS"
2510  GOTO 2710
2520  PRINT "YOUR CHOICE: LARGE WAVELETS OCCASIONAL"
2530  PRINT "FOAM CRESTS."
2540  GOTO 2710
2550  PRINT "YOUR CHOICE: SMALL WAVES - FREQUENT"
2560  PRINT "FOAM CRESTS"
2570  GOTO 2710
2580  PRINT "YOUR CHOICE: MODERATE WAVES-MANY CRESTS"
2590  GOTO 2710
2600  PRINT "YOUR CHOICE: LARGE WAVES - MUCH FOAM"
2610  PRINT "AND SPRAY BEGINNING TO FORM."
2620  GOTO 2710
2630  PRINT "YOUR CHOICE: SEA HEAPING UP"
2640  PRINT "BREAKING WAVES BLOWING SPRAY"
2650  GOTO 2710
2660  PRINT "YOUR CHOICE: MODERATELY HIGH WAVES"
2670  PRINT "FOAM BEING FLOWN IN STREAKS"
2680  GOTO 2710
2690  PRINT "YOUR CHOICE: HIGH BREAKING WAVES"
2700  PRINT "DENSE STREAKS OF FOAM"
2710  GOTO 2740
2720  PRINT "YOUR CHOICE: HURRICANE CONDITIONS"
2730  PRINT "VERY SEVERE SEAS"
2740  IF B < 5 THEN 3000
2750  IF B > 7 THEN 2770
2760  GOTO 3070
2770  PRINT
2780  PRINT "VERY SEVERE STORM. SEA CONDITIONS MAKE"
2790  PRINT "IT VERY DIFFICULT FOR AIR BREATHING"
2800  PRINT "ANIMALS TO COME TO THE SURFACE OF THE"
2810  PRINT "WATER. THE SURFACE IS A FOAM WATER"
2820  PRINT "INTERFERENCE WHICH HAMPERS BREATHING."
2830  PRINT
2840 S1 = S / 2
2850 T1 = T / 2
2860 D = S1 * T1 + D
2870 T = T + 1
2880  IF D > 2900 THEN 2910
2890  GOTO 2860
2900  PRINT
2910  PRINT : PRINT "OUT OF STORM. CONTINUE JOURNEY AT"
2920  PRINT "STANDARD RATE."
2930  PRINT
2940  PRINT "THE DISTANCE TRAVELED SO FAR = ";D;
2950  PRINT " KILOMETERS"
2960  PRINT "DAYS TRAVELED = ";T
2970  PRINT
2980  GOSUB 4910
2990  GOTO 3110
3000  PRINT
```

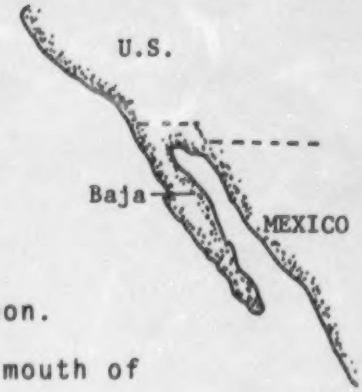
```
3010  PRINT "NOT A BAD STORM CONTINUE AT SAME RATE."
3020 D = S * T2 + D
3030 T = T + 1
3040  IF D > 2900 THEN 2910
3050  GOTO 3020
3060  PRINT
3070  PRINT "MILD STORM - SOME EFFECT"
3080 S1 = S / 2
3090 T1 = T
3100  GOTO 2860
3110  RETURN
3120  REM  WHALEWATCHING SUBROUTINE
3130  PRINT
3140  PRINT "YOUR WHALE IS OFF THE SOUTHERN "
3150  PRINT "CALIFORNIA COAST MOVING PAST THE"
3160  PRINT "POPULATION CENTERS OF LOS ANGELES"
3170  PRINT "AND SAN DIEGO WHERE MANY PEOPLE ENJOY"
3180  PRINT "WATCHING THE WHALE MIGRATION FROM BOATS"
3190  PRINT "CHOOSE A METHOD OF WHALEWATCHING:"
3200  PRINT
3210  PRINT "1 - SLOW APPROACH FROM THE REAR OF THE"
3220  PRINT "    ANIMALS AT THEIR SPEED GENTLY"
3230  PRINT "    MOVING CLOSER LEAVING THE MOTOR"
3240  PRINT "    RUNNING AT A CONSTANT SPEED."
3250  PRINT
3260  PRINT "2 - MORE RAPID APPROACH FROM BEHIND THE"
3270  PRINT "    ANIMALS SOME RACING OF THE ENGINE"
3280  PRINT "    TO CATCH THEM QUICKLY THEN SLOWLY"
3290  PRINT "    STAYING WITH THEM LONGER."
3300  PRINT
3310  PRINT "3 - RACING APPROACH TO GET TO THE "
3320  PRINT "    WHALES QUICKLY THEN SLOWING DOWN"
3330  PRINT "    TO STAY WITH THEM. IF THEY MOVE"
3340  PRINT "    MOVE AWAY RACE OVER TO THEM AGAIN"
3350  PRINT "    TO GET AS CLOSE AS POSSIBLE."
3360  PRINT
3370  INPUT "YOUR CHOICE OF 1 2 OR 3? ";O
3380  PRINT
3390  IF O = 1 THEN 3730
3400  IF O = 2 THEN 3640
3410  IF O = 3 THEN 3440
3420  PRINT "NO SUCH CHOICE. TRY AGAIN."
3430  GOTO 3370
3440  PRINT
3450  PRINT "THIS RACING TYPE OF WHALEWATCHING"
3460  PRINT "GREATLY DISTURBS THE WHALES CAUSING"
3470  PRINT "THEM TO USE AVOIDANCE BEAHAVIORS"
3480  PRINT "THEREFORE TIME IS LOST REACHING"
3490  PRINT "THE DESTINATION."
3500 S1 = 1
3510 T1 = 15
3520  FOR T9 = 1 TO 4
3530 D = S1 * T1 + D
3540 T = T + 1
3550  NEXT T9
3560  PRINT
3570  PRINT "LEAVING THE POPULATION CENTERS"
3580  PRINT "AND HARRASSMENT"
3590  PRINT "DISTANCE IS NOW ";D;" KILOMETERS."
3600  PRINT "ELAPSED TIME IS ";T;" DAYS."
3610  PRINT
3620  GOSUB 4910
3630  RETURN
3640  PRINT
3650  PRINT "MILD HARASSMENT TO THE WHALE WITH THIS"
3660  PRINT "TYPE OF WHALE WATCHING METHOD. IT"
3670  PRINT "HAS CAUSED THE WHALE TO SPEND TIME"
3680  PRINT "DODGING THE WHALE WATCHERS THEREBY"
3690  PRINT "DELAYING THE TRIP TO THE LAGOONS."
3700 S1 = 2
3710 T1 = 20
3720  GOTO 3520
3730  PRINT
3740  PRINT "VERY EFFECTIVE WHALEWATCHING CAUSED "
3750  PRINT "NO DISTURBANCE TO THE WHALE AND"
3760  PRINT "THEREFORE DID NOT SLOW IT DOWN. THE"
3770  PRINT "DID NOT USE AVOIDANCE BEHAVIORS"
3780  PRINT "OR CHANGE ITS SPEED OR CHANGE ITS"
3790  PRINT "DIRECTION. THIS METHOD IS USED"
3800  PRINT "SUCCESSFULLY TO OBSERVE THE WHALES"
3810  PRINT "BY HUNDRED OF SKILLED OPERATORS YEARLY."
3820  GOTO 3560
3830  REM  KILLER WHALE ENCOUNTER SUBROUTINE
3840  IF K1 = 0 THEN 3920
3850  PRINT
3860  PRINT "KILLER WHALES ENCOUNTERED AGAIN"
3870  PRINT "ENTER YOUR CHOICE OF DEFENSE BY"
3880  PRINT "USING THE 1 2 3 CHOICES"
3890  PRINT
3900  INPUT P
3910  GOTO 4130
3920  PRINT
3930  PRINT "YOU HAVE ENCOUNTERED A GROUP OF "
3940  PRINT "KILLER WHALES. THESE ANIMALS ARE"
3950  PRINT "POTENTIAL PREDATORS AND THEIR PRESENCE"
3960  PRINT "DISTURBS YOUR WHALE. HOW DO YOU "
3970  PRINT "CHOOSE TO REACT TO THEM?"
3980  PRINT
3990  PRINT "1 - TRY TO SWIM AWAY QUICKLY"
4000  PRINT
```

```
4010  PRINT "2 - STOP ANY SOUND PRODUCTION"
4020  PRINT "   (VOCALIZATION) & SWIM AWAY IN AN"
4030  PRINT "   EVASIVE MANNER TO THE KELP BEDS'
4040  PRINT "   GENERAL AVOIDANCE BEAHAVIORS"
4050  PRINT
4060  PRINT "3 - NO CHANGE IN BEHAVIOR JUST"
4070  PRINT "CONTINUE IN THE SAME MANNER IGNORING"
4080  PRINT "THEIR PRESENCE"
4090  PRINT
4100  PRINT "WHICH METHOD WILL YOUR WHALE FOLLOW?'
4110  PRINT
4120  INPUT P
4130  IF P = 1 THEN 4200
4140  IF P = 2 THEN 4310
4150  IF P = 3 THEN 4310
4160  PRINT
4170  PRINT "NO SUCH CHOICE IS AVAILABLE"
4180  GOTO 4120
4190  PRINT
4200  PRINT "AT WHAT SPEED IN KM/HR DO YOU WISH"
4210  PRINT "YOUR WHALE TO ESCAPE?"
4220  PRINT
4230  INPUT P1
4240  IF P1 > 12 THEN 4500
4250  PRINT
4260  PRINT "YOUR WHALE'S SWIMMING SPEED OF ";P1;
4270  PRINT "KM/HR IS SLOWER THAN THE 24 KM/HR THAT"
4280  PRINT " A KILLER WHALE IS ABLE TO SWIM"
4290  PRINT "THEREFORE  THE KILLER WHALES COULD"
4300  PRINT "EASILY OVERTAKE YOUR WHALE."
4310  REM  RANDOM 20% ATTACK RATE
4320  LET K2 =  INT (10 *  RND (1)) + 1
4330  IF K2 <  = 2 THEN 4380
4340  PRINT
4350  PRINT "THE KILLER WHALES ARE NOT INTERESTED'
4360  PRINT "AT THIS TIME. YOUR WHALE HAS ESCAPED."
4370  RETURN
4380  PRINT
4390  PRINT "THE KILLER WHALES ARE ATTACKING "
4400  PRINT "YOUR WHALE."
4410  PRINT "THE OUTCOME IS..."
4420  IF  RND (1) < .3 THEN 4460
4430  PRINT
4440  PRINT "YOU HAVE ESCAPED WITH ONLY A FEW SCARS."
4450  RETURN
4460  PRINT
4470  PRINT "THE KILLER WHALES HAVE DESTROYED"
4480  PRINT "YOUR WHALE."
4490  GOTO 4550
4500  PRINT "A GRAY WHALE CANNOT SWIM THAT FAST"
4510  PRINT "PLEASE TRY AGAIN."
4520  GOTO 4200
4530  PRINT : PRINT
4540  PRINT
4550  PRINT "WOULD YOU LIKE TO TRY AGAIN?"
4560  PRINT
4570  INPUT R$
4580  IF  LEFT$ (R$,1) = "N" THEN 4610
4590  PRINT
4600  GOTO 30
4610  PRINT : PRINT "THANK YOU FOR PLAYING THE GRAY WHALE"
4620  PRINT "MIGRATION LEARNING GAME."
4630  PRINT
4640  PRINT "** A COMMUNITY EDUCATIONAL RESOURCES **"
4650  PRINT "              ** PRODUCTION **"
4660  PRINT
4670  PRINT "DEPT. OF EDUCATION SAN DIEGO CALIFORNIA"
4680  PRINT ;GOSUB 4910
4690  PRINT
4700  PRINT "          XX"
4710  PRINT " XX. .....XX"
4720  PRINT " XXXXXXXXXXX"
4730  PRINT "   XXXXXXXX"
4740  PRINT "    XXXXXX"
4750  PRINT "     XXXX"
4760  PRINT "      XXX        .XXXXXXXXXXX."
4770  PRINT "      XX        .XXXXXXXXXXXXX."
4780  PRINT "     XXX       .XXXXXXXXXXXXXXXX."
4790  PRINT "    XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX."
4800  PRINT "    XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX."
4810  PRINT "    XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX."
4820  PRINT "   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX."
4830  PRINT "   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX."
4840  PRINT "   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX."
4850  PRINT "    XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX."
4860  PRINT "    XXXXXXXXXXXXXXXXXXXXXXXXXXXXX."
4870  PRINT "     XXXXXXXXXXXXXXXXXXXXXXXXXX."
4880  PRINT "     XXXXXXXXXXXXXXXXXXX........"
4890  PRINT "      XXXXXXXXXXXXXXXXXXXXXXXXXX"
4900  END
4910  PRINT "DEPRESS THE ";: INVERSE : PRINT "RETURN";
4920  NORMAL : INPUT " KEY TO CONTINUE.";IN$
4930  PRINT
4940  RETURN
```

Program Variables

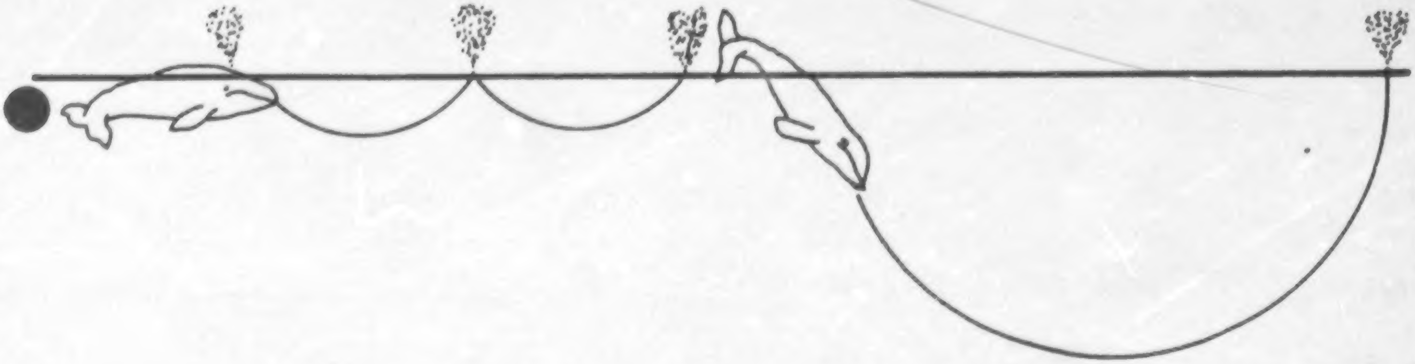
The following list represents the program variables used in the gray whale computer simulation.

B	Weather severity (Using Beauford wind scale)
C	Whale watching subroutine marker - prevents more than one occurrence
D	Elapsed distance in kilometers
D1	Starting location, choice is then assigned a numerical distance, referenced from Pt. Barrow = 0 kilometers
D2	Final destination, choice is then assigned a numerical distance, referenced from Pt. Barrow = 0 kilometers
D3	Total distance to swim (D2-D1) in kilometers
F	Initializes food encounter to zero, then assumes value of the random number generator for food encounter
F1	Food encounter repeat marker, prevents more than one occurrence
K	Killer whale random number generator variable
K1	Killer whale repeat marker
O	Whale observation method
P	Killer whale avoidance choice
P1	Killer whale avoidance speed
R	Repeat player marker
R1	Repeat marker for location information
S	Swimming speed in kilometers per hour
T	Elapsed time in days
T1	Number of hours per day spent swimming during an encounter
T2	Time spent swimming per day normally
T3	Time limit to reach lagoon (90 days)
T4	Four-day time penalty from harassment



FEBRUARY 21

Our whale and her baby leave the nursery lagoon. Together they swim the nearly thirty miles to the mouth of the lagoon. Our little female has grown to nearly 20 feet in length. She has more than doubled her weight. Her new muscle and blubber will help her to make the long swim north to the Arctic. Our mother and calf join others near the entrance to the lagoon.



Swimming near the entrance, the whales wait for calm seas and a high outgoing tide. These conditions let the weaker nurslings leave the lagoon with little risk. Not all of the these newborn will spend the summer in the Arctic. Already the carcasses of a number of baby whales are scattered along the beaches. Not all of the adults will be returning north. The beaches also have become the final resting place for over a dozen adults.

1. Where will the newborn whales spend their first summer?

The tide changes. Our healthy female calf follows close by her mother's side through the narrow channel and into the open ocean. On this day we lose sight of our whales.

In spite of extensive surveys and studies, we know very little about the next four months of our whales' lives. Some gray whales are seen migrating north past California, Oregon and Washington. These whales tend to be farther out to sea than when going south. They also tend to be males and females without calves. In April, large groups of gray whales gather off of Washington's Olympic Peninsula and British Columbia's Vancouver Island. But, here again, there are very few cows and calves.

Our female and her calf seem to have gone westward toward the open waters of the Pacific Ocean. In June, they reappear in the Arctic. The lengthening Arctic days have caused the phytoplankton populations to explode. The abundance of these tiny plants has allowed the zooplankton populations to also explode. These zooplankton populations provide food for our whale and new newborn calf.

2. Scientists know very little about the travels of mother and calf gray whales after they leave Scammon's Lagoon. How could scientists gather information about these travels? Design a research study that will provide you with information about these travels. Follow the format below:

   a. I will gather the information by ____________________

____

____

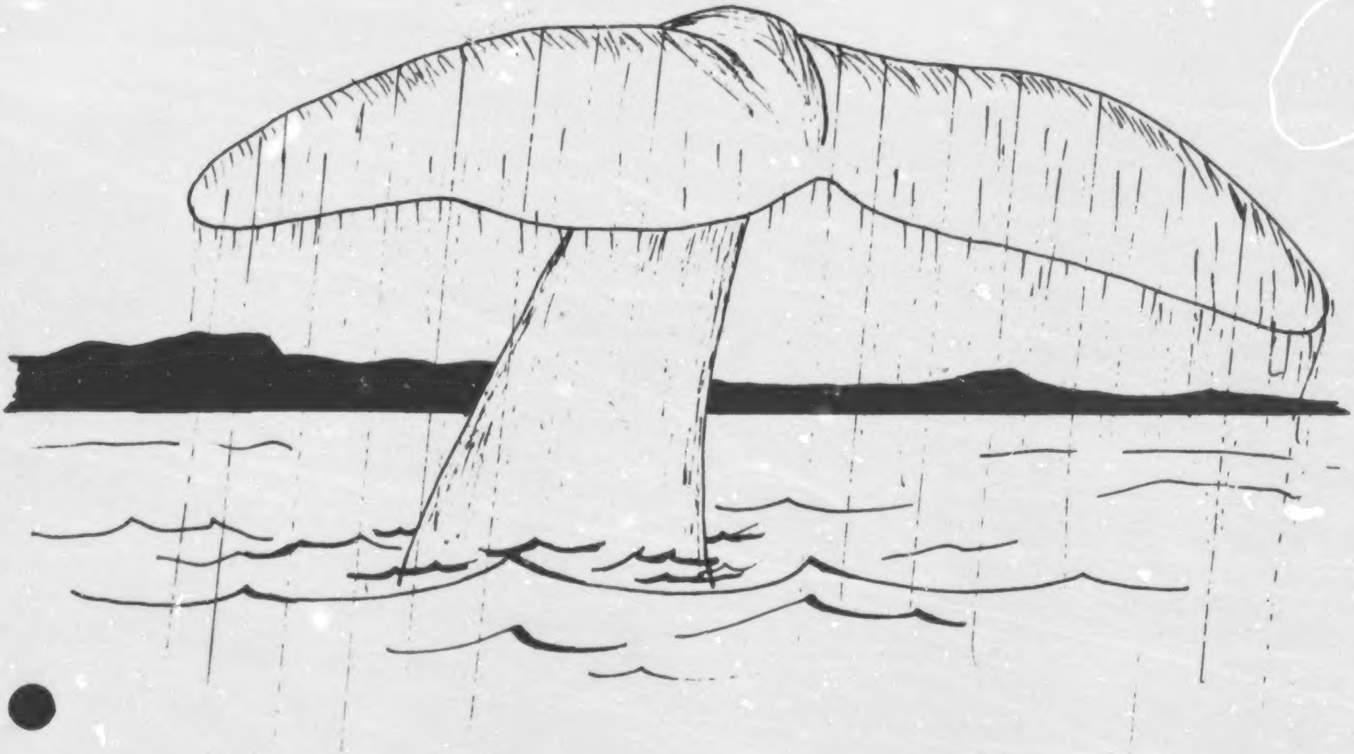
b. I will need to use the following things: ________

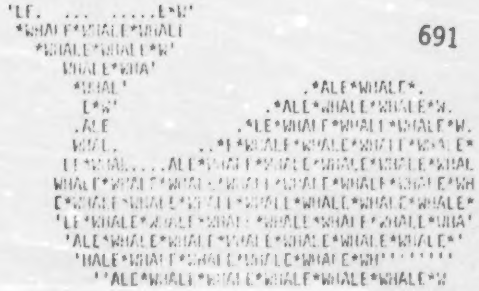
____

____

____

Fourteen thousand miles of travel have brought our whale back to the Siberian Arctic that she left in October. For the next four months, she and her calf will feed on the abundant plankton and bottom dwellers among the ice floes. They will feed until the shortening days of fall cause them to turn southward. Once again the most incredible migration known to man will occur.





THE ELECTRONIC WHALE

The annual migration of the California gray whale is one of nature's most remarkable journeys. The activity which follows is a computer simulation of this 11,000 kilometer (7,000 mile) trip. A computer simulation models or represents real life. This particular simulation allows you to experience some of the encounters that face gray whales on their long annual migration. As with any model, certain assumptions are made. The assumptions are based on what we know about gray whales. Within the limits of our knowledge and technology, the simulation represents a good picture of the migration.

The simulation is designed to allow you to choose your whale's response to various encounters. No two runs of the simulation will be exactly alike. If time permits, run the simulation several times. Select different reponses each time and study your results.

Materials:

record sheet

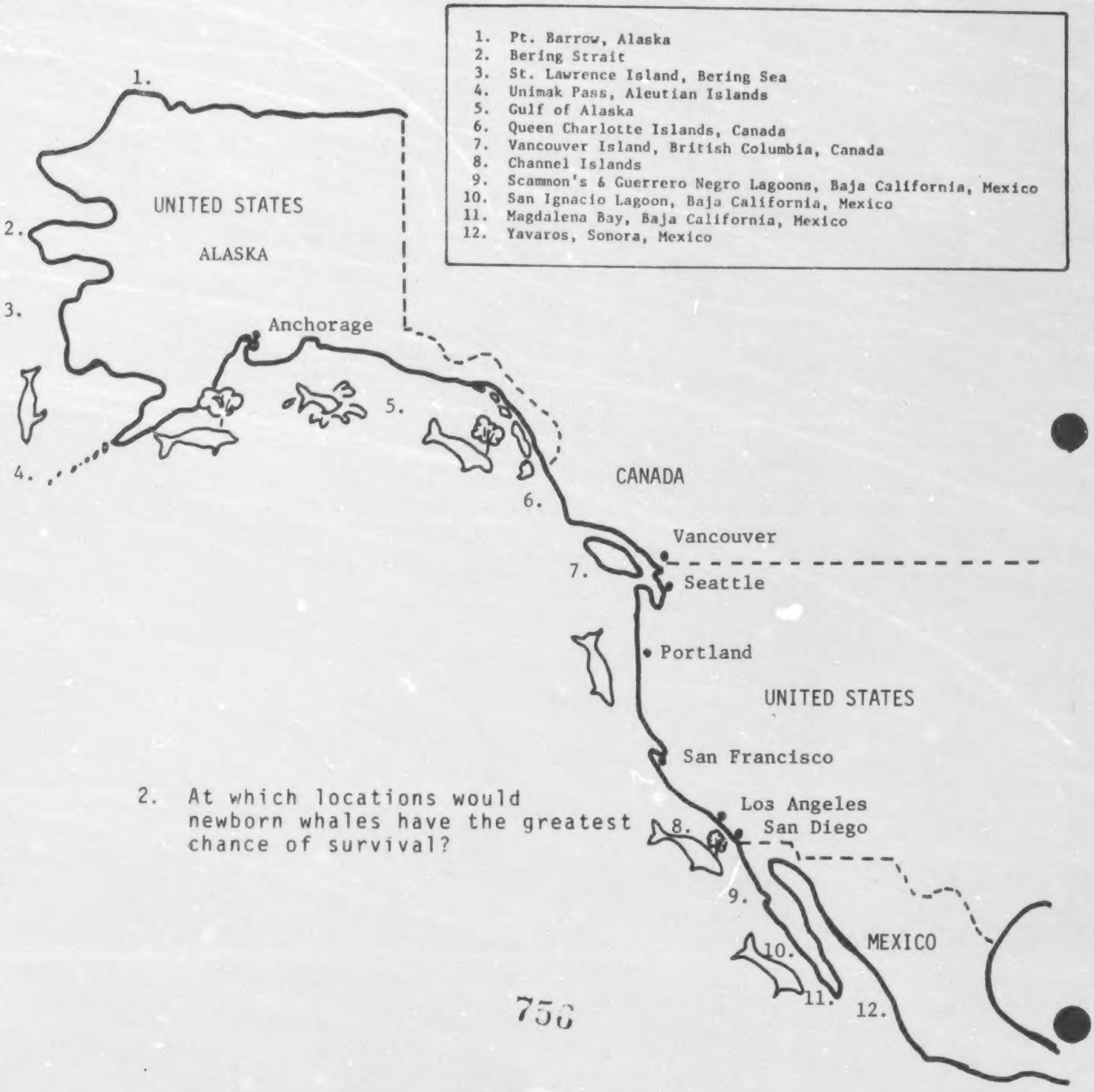
pencil

computer terminal

Procedure:

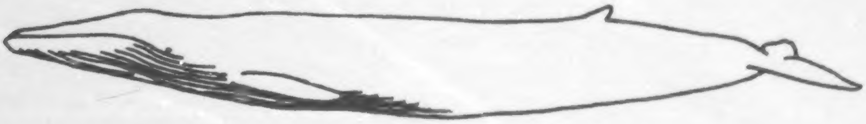
Follow your teacher's instructions regarding how to start the simulation. You will first be asked to select a location for the start of your whale's migration. The map on the next page will help you locate your choice.

1. At which locations is summer food supply the greatest?

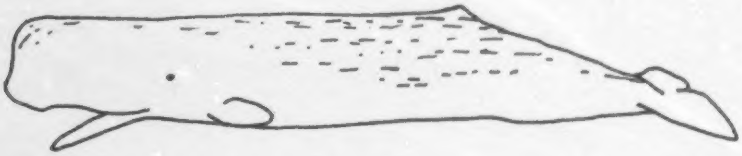

1. Pt. Barrow, Alaska
2. Bering Strait
3. St. Lawrence Island, Bering Sea
4. Unimak Pass, Aleutian Islands
5. Gulf of Alaska
6. Queen Charlotte Islands, Canada
7. Vancouver Island, British Columbia, Canada
8. Channel Islands
9. Scammon's & Guerrero Negro Lagoons, Baja California, Mexico
10. San Ignacio Lagoon, Baja California, Mexico
11. Magdalena Bay, Baja California, Mexico
12. Yavaros, Sonora, Mexico
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
UNITED STATES
ALASKA
Anchorage
CANADA
Vancouver
Seattle
Portland
UNITED STATES
San Francisco
Los Angeles
San Diego
MEXICO

2. At which locations would newborn whales have the greatest chance of survival?

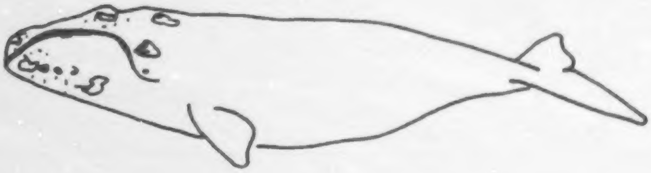
Next, you will be asked to select a swimming speed for your whale. Whales can travel for long periods of time at rates from 3 kilometers to 46 kilometers (2 to 25 knots) per hour. The chart below shows some whales and their long distance swimming speeds.



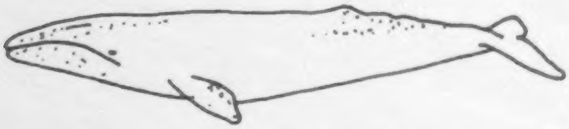
Fin whale
(22-26 km/hr)



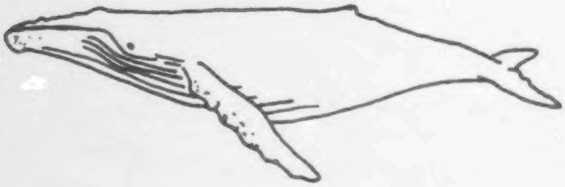
Sperm whale
(18-37 km/hr)



Right whale
(3-9 km/hr)



Gray whale
(4-12 km/hr)



Humpback whale
(10-18 km/hr)

Once you choose the starting location and speed, your whale is ready to begin the southward migration. The computer is programmed for the whale to swim 24 hours a day. Scientific studies seem to support this assumption.

3. At your chosen rate of speed, how many kilometers per day would your whale cover? (Hint: There are 24 hours per day).

Along the migratory route, the computer will present various problem encounters such as storms and predators. Read each encounter carefully as it is presented. Select a possible solution for each problem. If you run the program more than once, try to select different reponses in each run. RECORD your whale's progress on the record sheet. If your computer terminal makes a printed copy, save it for comparison and discussion with others.

Good luck to your whale and have fun.

CALIFORNIA GRAY WHALE COMPUTER SIMULATION STUDENT RECORD

Name ______________________ Grade ______ Teacher ______________________

Run No.	Starting Location	Final Destination	Speed Choice/Result		Weather Choice/Result		Killer Whale Choice/Result		Channels In	Channels Out	Whalewatch

Superintendent of Schools, Department of Education, San Diego County

SEND-IN PAGE

Well, you've made it. Thank you for teaching about the marine environment. We worked hard to put this unit together and we would really like to hear from you. If you have any reactions (positive or negative) that could help us, please let us know. We are also interested in any changes you made in the activities which you feel made them more useful. If you have some marine activities that you have tried successfully with children, we would like to know about them also. Perhaps we can help you share your working ideas with other teachers concerned with the marine environment. Again thanks, and keep up the good work.